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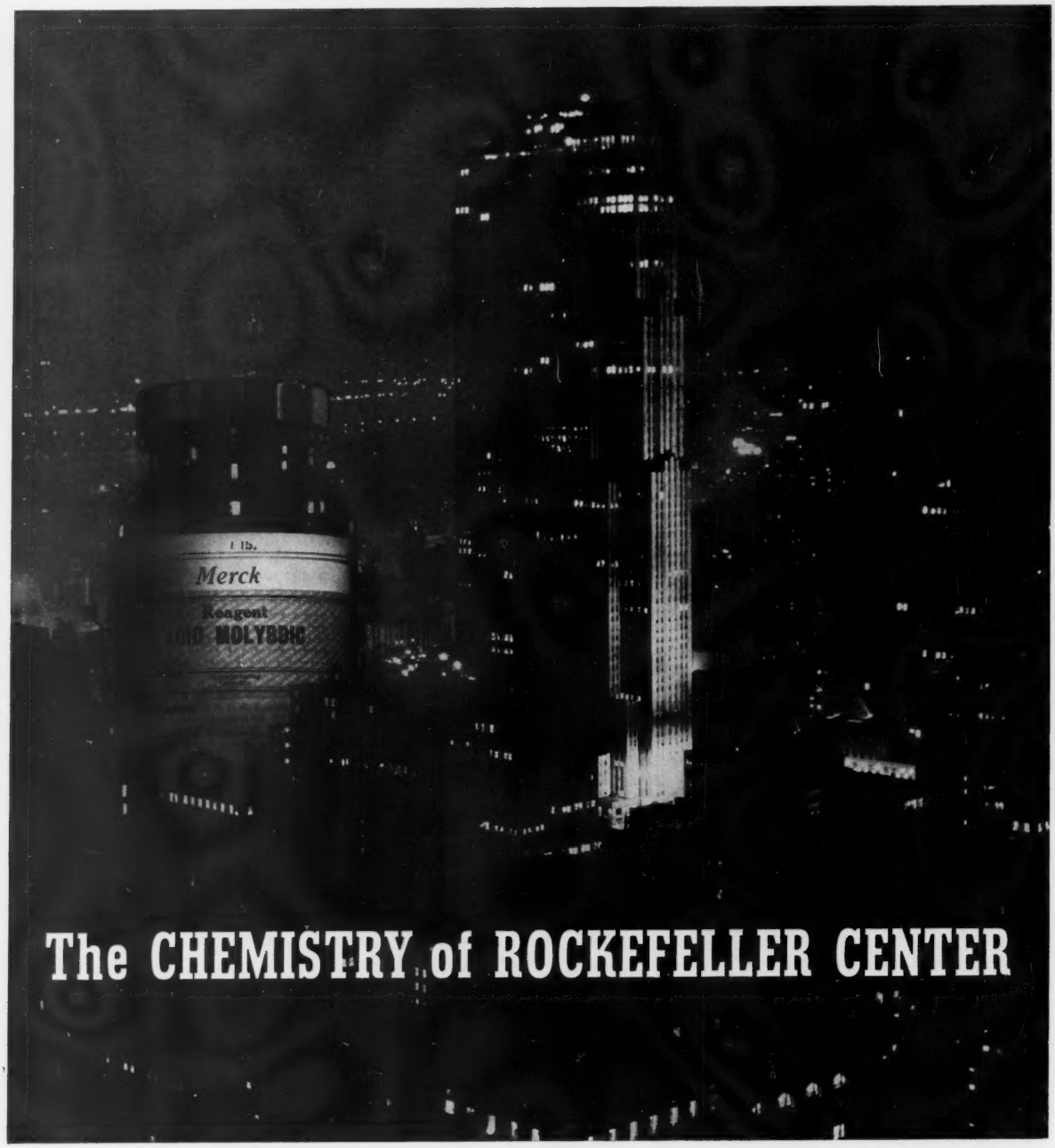

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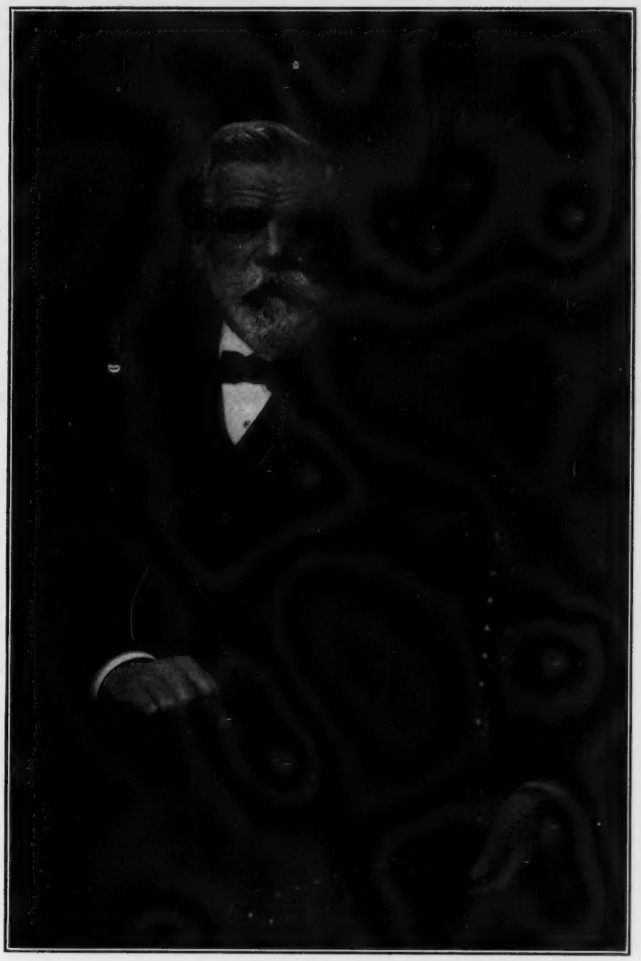

ERNEST SOLVAY (1838–1922)

Ernest Solvay, who made his name synonymous with soda, was born on April 16, 1838, at Rebecq, Belgium. His father, a quarry master, pieced out his modest income by refining salt on a small scale and Solvay, remembering the large tubs that stood in the yard, often remarked that he grew up in an atmosphere of sodium chloride. At school he was interested in science, particularly chemistry, and with his younger brother Alfred spent most of his free time in their home-made laboratory. Delicate health forced Ernest to leave school at an early age; his formal education was over, thenceforth he taught himself. By reading and study he widened the narrow horizon of village life, and developed the self-reliance, resourcefulness, and independence of judgment that characterized his adult life.

Sent to Antwerp to learn bookkeeping, the sixteen-year-old boy proved to be a mediocre clerk, "only the universe occupied his thoughts." At eighteen he was given a place in the gas works directed by his uncle Semet. His routine duties allowed him time for the chemical experimenting that was always uppermost in his mind. The by-products of the gas works, both a nuisance and a waste, were a serious problem; the ammonia especially aroused his interest. He mixed solutions of sodium chloride and ammonia and passed in carbon dioxide: a white precipitate resulted. This simple observation was the birth of the Solvay process.

The reaction was simple, but it took five years of heart-breaking toil by the Solvay brothers to bring its application to the commercial stage. The parents poured their savings into the venture, failure followed failure, but with indomitable faith in himself Ernest persisted. "If at times I am discouraged it is because I feel that despite my will power I am losing confidence in my strength." In 1866 the last of the family's funds went into new apparatus; the outlook brightened. "After being so often within an inch, a hair's breadth of failure, shall I finally succeed in regaining from others and from myself that moral strength which the whole world seems to deny me? After all that has happened this would indeed be a splendid triumph. Let us not speak of it, we are now too used to set-backs." By December, 1867, the Solvay process was a commercial reality. The Le Blanc process was rapidly displaced, the consumption of soda rose fifteen fold, the price dropped seventy-five per cent. Solvay became one of the richest industrialists of his day.

Attempts were made to belittle Solvay's accomplishment. The basic reaction was not his discovery, but others had found that their patents were useless because they could not surmount the problems entailed, especially proper equipment and excessive loss of ammonia. Solvay, less than thirty, with only a smattering of scientific education, with little money and no worth-while connections, succeeded by hard work, ingenuity, and faith in himself. "The point of departure of this result was not a scientific precept, I was neither engineer nor chemist, and I knew only the laws of Berthollet." With justifiable pride he declared, "I have established the manufacture of soda using ammonia when there had been only abandoned attempts."

The management of his business he left to others; he devoted himself to philanthropic and scientific inquiries. He rose early, worked late, fashionable society saw little of him. He set himself the tremendous tasks of solving the problem of the physical universe and the social world. "The living being is a physico-chemical reaction. Society, like the individual, acts automatically. The laws which it obeys are summarized in the human and physiological law of the search for the best existence, which is itself only a veiled expression of the physico-chemical law of maximum work." From this mechanistic viewpoint, he believed that sociological and political problems can only be solved by application of the rational methods of science.

Realizing that these tasks were too great for any one man, he founded at Brussels the Solvay Institutes of Electro-Physiology, Social Sciences, Chemistry, Physics, which would serve "to con-

(*Please turn to page 424*)

EDITOR'S OUTLOOK

"INFORMATION, PLEASE." At various times in the past we have made use of these columns to toss off suggested recipes for the sugar-coating of one or another educational pill. At the risk of confirming some of our readers in their tentative suspicions that we are insufficiently impressed by the reality and earnestness of the academic life, we would like to set before you another little confection that we whipped up the other night after the cook had gone home. There is nothing very exotic about the ingredients, and the basic theme of the composition is no more original than the idea that the acquisition and display of knowledge can be a lot of fun.

We would like to get off to as good a start as possible by protesting that we have no sympathy with the view that it is the teacher's primary duty to be entertaining. Moving pictures, radio, and the musical comedy stage are among the more appropriate environments for the born entertainer. On the other hand, we submit that there is neither virtue nor efficiency in a sour-pussed attitude toward what are sometimes regrettably termed The Serious Things of Life. We are just pessimist enough to believe that it behooves the traveler through this vale of tears to enjoy every bit of available fun that does not involve injury to others, prejudice to his own future, or neglect of his present responsibilities. "Strength through joy" is a lousy translation of about the only Nazi slogan to which we heartily subscribe.

Spurred on by our insatiable interest in sociological phenomena and popular psychology, we have followed the radio sponsors to the conclusion that people love to answer questions, if only the stage be properly set. On our own modest radio set we can tune in some six or eight quiz programs weekly—and without resort to the static-bedeviled short-wave bands, at that. In some, the quiz is directed at persons chosen more or less at random from the studio (or street-corner) audience. In others, teams volunteering for the contest compete. In one, at least, a group of studio "experts" pits its wits against those of the general public. Incidentally, most of the questions posed are selected from those submitted by the radio audiences. (People love to ask questions, too.)

Numerous ways in which these various entertaining quiz technics can be adapted to useful classroom purposes will readily suggest themselves to the teacher who finds the idea at all attractive. In such adaptations provision may well be made to permit the class the privilege of asking as well as answering questions. It sometimes requires quite as much knowledge and ingenuity to frame a good question as it does to answer one.

We recall from our own school days a little classroom game that was always welcomed by the students, and that still seems to us to have educational merit. The course was one in the identification of organic compounds. A group, usually of three "experts" (supported in emergencies by the instructor), answered questions as to the properties and reactions of a compound agreed upon among themselves. It was the purpose of the "experts" to answer all questions correctly. The remainder of the class undertook to deduce from the answers the identity of the compound selected. In the occasional periods devoted to this pastime, we covered a range of compounds and characteristic reactions that we could never have got over in the laboratory, and to most of us it was more fun.

We shall be interested to learn from any of our readers of other adaptations of the informal quiz.

COUNT MICHAEL MAIER'S USE *of the* SYMBOLISM OF ALCHEMY*

TENNEY L. DAVIS

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THE theory of alchemy was simple and obvious. All material objects were the result of the interaction or combination of Two Contrary First Principles. Gold, the perfect metal, was the perfect combination of the Two Principles, "without superfluity or defect." To prepare gold it was necessary only to procure the Two Principles, each in a state of purity, and then to bring about their combination in the proper proportion. Equally, being given a base metal which was an imperfectly adjusted combination of the Two Principles, it was needful only to adjust the proportions, to remove the superfluities and defects, to accomplish the transmutation of it into perfect gold.

The ancient theory is as simple as our present theory and practice of transmutation. To procure whatever element we wish, it is now needful only to secure the proper combination of protons, electrons, and neutrons. The thing which must be done is clear enough, and it has been accomplished in a number of cases. But our powers are limited; in modern science, as in earlier alchemy, the knowledge of what must be done and the knowledge of how to do it are not always associated.

From time immemorial man has apprehended and described natural objects and phenomena by means of the positive and negative qualities which they exhibit. Hot and cold are opposites, and every material object according to its nature possesses in a greater or less degree the qualities of warmth and coldness. So it is also with any other pair of opposite qualities which we may choose to mention. Every object possesses more or less of one and the other of them. Distinction between the qualities by means of which an object is apprehended and the substance of which it truly consists is difficult to make, perhaps impossible, probably profitless. At any rate, the oldest scientific doctrine of which any evidence has survived taught that all material objects consist of combinations of Two Contrary Principles, one of them having all of the positive qualities, active, hot, dry, light, and spiritual; the other all of the negative qualities, passive, cold, wet, heavy, and material.[1] Since these Contraries were difficult to describe precisely, they were designated by names having broad connotations; they were associated with deities, with the two regulating powers of the universe, one of

FIGURE 1

THE PREPARATION OF THE PILL OF IMMORTALITY ACCORDING TO CH'ÊN KUAN-WU

The Yang principle is represented by the man, by the dragon and by fire; the Yin principle by the woman, by the tiger and by water in the forms of clouds, rain, and hail. The tortoise and the serpent, symbolizing the material embodiments of the Yang and Yin principles, further represent the combination of the Two Contraries. From *Chin Tan Ta Yao* (Essentials of the Gold Medicine) written by Ch'ên Kuan-Wu or Shang-yang-tzŭ during the reign of the Yüan Emperor Wên (1329–1332 A.D.), reproduced from the Ming edition printed during the reign of the Ming Emperor Ying Tsung, reign title Chêng T'ung (1436–1450).

* Slightly altered from a paper read at Wellesley College, March 2, 1938, at the time of the presentation of a paper by Professor Helen J. Sleeper on "The Alchemical Fugues in Count Michael Maier's *Atalanta Fugiens*" in connection with the singing by a choir of Wellesley and Technology students of certain of the fugues rendered into modern notation by Professor Sleeper. The program of which the presentation of these two papers was a part was conceived and arranged by Professor Ruth Johnstin, whose interest in Michael Maier was responsible for the discovery and purchase of a copy of *Atalanta Fugiens* by the Wellesley College Library. Professor Johnstin also persuaded Miss Robathan to undertake the Latin translations.

[1] For a fuller discussion of this point, see J. CHEM. EDUC., 12, 3–10 (1935).

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them the principle of activity, the other the principle of material acted upon; they were designated by names which are to be taken as symbols suggestive of all of the qualities which each of them possessed. Some, but not all, of the commonest traditional identifications are indicated in Table 1. The Emerald Table of Hermes Trismegistos, a sincere exposition of the primitive doctrine, both cosmogony and metaphysics, the Hermetic Table which later European alchemy adopted as its Book of Revelation, says,

That which is below is as that which is above, and that which is above is as that which is below, for accomplishing the miracles of a single thing. And as all things were from one, by the meditation of one, so all things were born from this one thing, by adaptation. The father of it is the Sun, the mother of it the Moon. . . . So the world was created. Hence there will be marvelous adaptations of which this is the mode.

TABLE 1

THE TWO CONTRARY PRINCIPLES

Ancient	Positive		Negative	
	Active		Passive	
	Osiris		Isis	
	Baal, Bel		Astarte, Astaroth, Ishtar	
	Shiva		Parvati	
	Father		Mother	
Latin Alchemy	King		Queen	
	Sun		Moon	
	Man		Woman	
	Fire	Chinese Yang Dragon	Water	Chinese Yin Tiger
	Hot		Cold	
	Volatile		Fixed	
	Sulfur		Mercury	
18th Century	Phlogiston		Calx	

For Chinese alchemy the Two Principles were Yang and Yin, Sun and Moon, Fire and Water, Dragon and Tiger, and so forth, identical with the Sulfur and Mercury Principles of the European alchemists whose words must not be taken to mean common yellow combustible brimstone and the liquid white metal which we call mercury.

The Two Principles could be represented as easily by pictures as by words, and the alchemical process by which they were made to combine for the production of gold, of the pill of immortality, or of the Philosopher's Stone, has been represented repeatedly in Chinese and in European early manuscripts and later printed books by pictures which may be considered to be legitimate, and clear, representations of alchemical theory.[2]

The earliest known treatise on alchemy, the *Ts'an T'ung Ch'i* of Wei Po-Yang, written about A.D. 142, describes the preparation of the pill of immortality by the heating together of the Two Principles in a closed vessel from which no vapors could escape, at first gently and finally with a strong fire. The hermetically sealed vessel, which the later European alchemists denominated the "Philosopher's Egg" and pictured accordingly, is described by Wei Po-Yang.

On the sides there is the walled enclosure, shaped like a *P'eng-hu* pot. Closed on all sides, its interior is made up of intercommunicating labyrinths. The protection is so complete as to turn back all that is devilish and undesirable, and the meandering passages take good care of emergencies.[3]

The tortuous passages serve as reflux condensers for the return of volatile material. The Principles themselves are indicated by allegorical names.

In order that the Treatise on Fire shall not have been in vain, I shall explain here in simple language. Like the moon lying on its back is the shape of the furnace and the pot. In it

FIGURE 2

CH'ÊN KUAN-WU'S "DIAGRAM OF THE MEDICINE LABORATORY OF TZŬ-YANG"

This is a table of contraries, the entities and qualities named on the left-hand half of the page (where the tiger is pictured) being negative, those on the right-hand half (where the dragon is pictured) being positive. The laboratory for the preparation of the medicine is clearly the place where the contraries are brought together.

is heated the White Tiger. Mercury Sun is the flowing pearl and with it is the Blue Dragon. The east and west merge together, and so the *hun* and *p'o* control one another. . . . . The Red Bird is the spirit of fire and dispenses victory or defeat with justice. With the ascendance of water comes the vanquishing of fire.[4]

The process itself:

Treatment and mixing will bring about combination and rapid entrance to the scarlet portal. The escape must be firmly

[2] Concerning the essential identity of Chinese and European alchemical theory and symbolism, see *Isis*, **28**, 73–86 (1938).

[3] *Isis*, **18**, 236 (1932).

[4] *Ibid.*, pp. 239–40.

blocked. Below plays the dazzling flame, while the Dragon and Tiger keep up a sustained vociferation. The flame at the start should be weak, so as to be controllable, and should be made strong at the end. Close attention and careful watch should be

FIGURE 3

AN ALCHEMIST'S LABORATORY. THE SIXTH KEY OF BASIL VALENTINE

The combination of the Two Principles for the production of the Philosopher's Stone. The intent of this picture is strikingly similar to that of Figure 1. The Sulfur principle is represented by the Sun, by the King and by fire; the Mercury principle by the Moon, by the Queen and by water. (Note that the clouds above the Queen are not radiant as are those above the King.) The instruments in the foreground are the means by which the marriage is to be consummated. The goose symbolizes a "goose-neck" or retort. Wood-cut from the third German (Hamburg, 1700) edition of Basil Valentine's collected chemical writings.

given so as to regulate properly the heat and cold. . . . . The color changes into a purple. Behold! the Returned Medicine is obtained. This is then made into pills. These are extremely efficacious, although their individual size is so small that they occupy only the point of a knife or the edge of a spatula.[5]

The appearance of the materials is described in language which indicates that the author had observed chemical phenomena and had been impressed profoundly by them. There can be no doubt that the following passage is a description of a violent reaction accompanied by color changes and the production of a sublimate.

Above, cooking and distillation take place in the caldron; below blazes the roaring fire. Afore goes the White Tiger leading the way; following comes the Grey Dragon. The fluttering Scarlet Bird flies the five colors. Encountering ensnaring nets, it is helplessly and immovably pressed down and cries with pathos like a child after its mother. Willy-nilly it is put into the caldron of hot fluid to the detriment of its feathers.

FIGURE 4

HERMES, THE EGYPTIAN

From Michael Maier's *Symbola Aureae Mensae Duodecim Nationum*, 1617. The astrolabe represents the heavens, the landscape the earth: "That which is above is as that which is below," etc. The Two Contraries, the Sun and the Moon, the Sulfur and Mercury principles, are brought into combination by the agency of fire.

Before half of the time has passed, Dragons appear with rapidity and in great number. The five dazzling colors change incessantly. Turbulently boils the fluid in the furnace. One after another they appear to form an array as irregular as a dog's teeth. Stalagmites, which are like midwinter icicles, are spit out horizontally and vertically. Rocky heights of no apparent regularity make their appearance, supporting one another. When Yin and Yang are properly matched, tranquility prevails.[6]

To show the continuity of alchemical thought, we quote a description of the same process from the *Speculum alchemiae* which is ascribed to Roger Bacon, a treatise written more than a thousand years later than the *Ts'an T'ung Ch'i.*

Another says, "This work is similar in many respects to the creation of man, for, as a child is nourished at first with lighter foods until the bones are formed, then with stronger ones, so this magistery requires a slow fire by which it is acted upon in the manner of a decoction." And always when we speak of a slow fire, we mean that the fire is to be augmented and made stronger gradually and in successive stages during the course of the work. . . . .

[5] *Isis*, **18**, pp. 243–4.

[6] *Ibid.*, pp. 258–9.

If, then, we intend to imitate nature, we must necessarily have a furnace of the same sort, after the fashion of the mountain, not in size, but of such sort as to provide a continuous heat so that the fire imposed upon it shall not find an exit when it ascends and so that the heat shall reverberate the tightly closed vessel which contains within itself the material of the Stone. Which vessel ought to be round with a short neck, of glass or of earthenware corresponding to the nature and compactness of glass, and its mouth ought to be closed with a suitable stopper and coated and sealed with bitumen. And as in the mines the heat does not touch directly the substance of the Sulfur and of the Quicksilver, because the earth of the mountain is everywhere between, so the fire ought not to touch directly the vessel which

FIGURE 5

"ABOVE AND BELOW IT IS THE SAME; NOTHING IS ACCOMPLISHED WITHOUT FIRE."

Upper half of the title page of *Traité de la Chymie* by Christophle Glaser, 1667. The Sun and the Moon are made to combine by means of fire. The lower of the two faces represents the Moon, for no rays are emanating from it. The lion, swallowing the bird which is its own tail, symbolizes the unity of matter in respect to its twofold inner nature. The bird is the volatile Sulfur which is fixed (rendered non-volatile) by the Mercurial Lion.

contains the above-mentioned materials. But this vessel must be placed within another vessel similarly closed, so that a temperate heat may better and more aptly reach the material above and below and from whatever side it may be. Whence Aristotle says in the *Lumen Luminum* that Mercury is to be cooked in a triple vessel, which vessel may be of the hardest glass or what is better, of earthenware having the nature of glass.[7]

The two above-quoted descriptions of the alchemical process are sober descriptions. They make use of fanciful terms: we are not able to identify concretely the reagents (which surely never had a concrete existence anyway), but we do recognize that the reagents are the prime Two Principles; we note the mention of chemical apparatus and see clearly that a chemical process is described. The very words by which the Chinese process is described suggest pictures by which it may be symbolized. The terms, Sulfur and Mercury, for each of which the European alchemists had dozens of synonyms, correspond to similar pictorial representations.

In addition to practical laboratory workers, alchemy attracted imaginative, artistic, and poetic people, many of whom were not chemists at all, who found delight in its central doctrine and loved to adapt its analogies to the production of literary and pictorial beauty, to morals and ethics, to metaphysics and cosmogony, to religion and to matters of everyday life. Such a one was the anonymous author of *Le Texte d'Alchymie et le Songe-Verd*, who described the theory of alchemy with extraordinary clarity, though without giving indication that he had had laboratory experience, and ended his

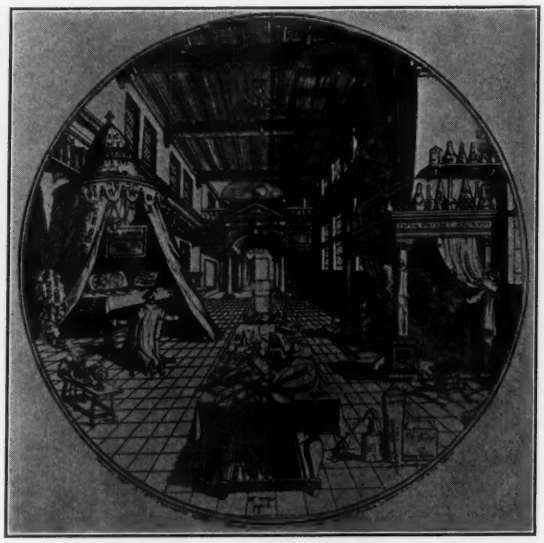

FIGURE 6

A LABORATORY FOR PRAYER, FOR MUSIC, AND FOR CHEMICAL OPERATIONS

From *Amphitheatrum Sapientiae Aeternae* by Heinrich Khunrath, 1609.

little work with an account of a "Dream Freshly Remembered" from which we quote a short passage which is not without beauty even in translation.

I asked him how they were able to preserve these flowers and fruits during the winter. He told me that they had no knowledge of winters, that their years had only three seasons, namely, spring, summer, and that of these two seasons a third was formed, namely autumn which shut up in the body of the fruits the spirit of spring and the soul of summer, and that it was in this season that the grape and the pomegranate were gathered, which were the best fruits of the country.[8]

This is an allegory of the alchemical process: the Grand Magistery is to be attained when the substance embodies

[7] *Theatrum Chemicum*, Vol. 2, pp. 438, 439–40, Ursellis, **1602**; J. CHEM. EDUC., **8**, 1950, 1951 (1931); *Isis*, **18**, 276–7 (1932).

[8] *Le Texte d'Alchymie et le Songe-Verd*, Paris, **1695**, p. 107. For an English translation of the whole treatise, see *The Monist*, **30**, 70–106 (1920), quoted passage, p. 103.

the fulfilled intent and accomplishment, when active and passive are properly balanced, when the material has acquired the desired attributes.

Another speculative alchemist was Heinrich Khunrath, theosophist and mystic, whose *Amphitheatrum Sapientiae Aeternae*, 1609, is illustrated with pictures which seem to have an alchemical significance but which really treats of cabalistic matters which have little relation to the history of chemistry. The first

ATALANTA
FVGIENS,
hoc est,
EMBLEMATA
NOVA
DE SECRETIS NATURÆ
CHYMICA,
Accommodata partim oculis & intellectui, figuris cupro incisis, adjectisque sententiis, Epigrammatis & notis; partim auribus & recreationi animi plus minus 50 Fugis Musicalibus trium Vocum quarum duæ ad unam simplicem melodiam distichis canendis pertaptam, correspondeant, non absq; singulari jucunditate videnda, legenda, meditanda, intelligenda, dijudicanda, canenda & audienda:
Authore,
MICHAELE MAJERO Imperial. Consistorii Comite, Med. D. Eq. cæs. &c.
OPPENHEIMII
Ex typographia HIERONYMI GALLERI
Sumptibus JOH. THEODORI de BRY,
M DC XVII.

FIGURE 7

TITLE-PAGE OF *Atalanta Fugiens*, FIRST EDITION, WELLESLEY COLLEGE COPY

"Atalanta Fleeing, that is, New Emblems of the Secrets of Chemical Nature: adapted partly to the eyes and partly to the understanding, in copperplates, with the addition of sentiments, epigrams and notes; partly to the ears and the refreshment of the mind, in about 50 fugues for three voices, whereof two are fitted to one simple tune, well suited to singing couplets; the whole most excellently pleasant to see, read, meditate, understand, judge, sing and hear."

of the folding plates of this folio volume is a picture of a laboratory in which musical instruments are shown, a place for prayer, for music, and for chemical experimentation. It is of particular interest to us because it is one of the relatively few places in which alchemy and music are affiliated.

The outstanding example of the association of alchemy with music is found in *Atalanta Fugiens*. Count Michael Maier, the author of the book, stands somewhere between the true alchemists, who practiced chemical operations and used the allegory of alchemy because they found it convenient, and the psychotic fringe, uninterested in chemistry, who made totem and fetish of alchemical symbolism and cult of its imagery.

TRES SCHOLA. TRES COESAR TITVLOS DE
DIT: HÆC MIHI RESTANT,
POSSE BENE IN CHRISTO VIVERE. POSSE MORI.
MICHAEL MAIERVS COMES IMPERIALIS CON
SISTORII etc. PHILOSOPH. ET MEDICINARVM
DOCTOR. P. C. C. NOBIL. EXEMPTVS FOR. OLIM
MEDICVS CÆS. etc.

FIGURE 8

COUNT MICHAEL MAIER

Forty-nine years old, as he appeared at the time of the publication of *Atalanta Fugiens*. From *Symbola Aureae Mensae Duodecim Nationum*, 1617.

He was a Doctor of Medicine and was certainly acquainted with chemical processes. He had more than the usual fondness for pictures. He was a learned and cultivated gentleman, and seems to have understood the principles of musical composition as well as anyone, not a great musician, could have understood them in his day. His *Atalanta Fugiens* is an alchemical picture book, "designed largely to illustrate the supposed relationships between alchemical doctrines and classical mythology,"[9] in which each of the fifty copperplate Emblems is accompanied by a verse or Epigram in Latin, with German translation, and by music for the singing of it. It is probably the only treatise on alchemy in which more than a few notes of music are printed.

[9] READ, JOHN, "Prelude to Chemistry," The Macmillan Co., New York City, 1937, p. 236.

The good fortune which made it possible for Miss Ruth Johnstin, Professor of Chemistry at Wellesley College, to procure for the College Library a copy of the extremely rare first edition, 1617, of *Atalanta Fugiens*,[10]

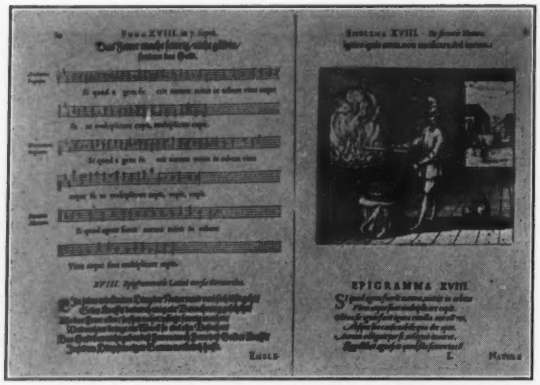

FIGURE 9

TWO PAGES OF *Atalanta Fugiens*, EMBLEM XVIII

"Whatever active force there may be in Nature sends its strength into the world, and wants it to increase. So fire makes everything that it comes in contact with fiery, and there is nothing that can produce a noble work without its own cause. Gold can not make fire by itself; fire does not make gold. Everything acknowledges its own seed."

The picture, which shows a basin full of gold coins in the foreground, perhaps ready to be put into the fire, signifies that seed is necessary for the successful preparation of additional gold. Possibly also it makes sly reference to the fact, often mentioned by the alchemists, that the gold-making art is an expensive one to practice.

the interest of Miss Dorothy Robathan, Assistant Professor of Latin, in scanning and translating the Epigrams,* and of Miss Helen J. Sleeper, in converting the music into modern notation and in training the singers, have made it possible for a choir of ten Wellesley and six Technology students to perform the musicohermetic archeological experiment of singing Michael Maier's fugues Nos. X, XVIII, XXII, XXVII, XXXI, XXXVI, and XLV.†

Michael Maier was born in 1568 at Rendsburg in Holstein, about nineteen miles west of Kiel at a place situated to the north of the present canal. He is said to have graduated as Doctor of Medicine at Rostock in 1597, and is further reported to have left Holstein in 1608 at the age of forty with a reputation already established. Soon afterward he was appointed physician to the Emperor Rudolf II at Prague, who conferred on him the rank of *Pfalzgraf* or Count Palatine, and made him his private secretary. Rudolf II was a generous and understanding patron of science, deeply interested in the work of the alchemists who flocked to his court. Here Michael Maier undoubtedly participated in alchemical discussions and experiments. Here his omnivorous appetite for reading must have found satiety in the splendid library of the Emperor. Here his imagination must have been fired for the production of the works which he published in rapid succession during the years 1614 to 1620. Rudolf II died in 1612. Maier left Prague in the same year, going to Magdeburg, where he established his permanent residence and practiced medicine until his death in 1622. While residing at Magdeburg, he traveled from time to time in Germany, visited Prague, and sought the acquaintance of alchemists in England, where he improved his English and translated Norton's "Ordinall of Alchimy" into German. In 1619 he was appointed physician to the Landgrave of Hesse. In religion he was a Lutheran and an early follower of the secret mysticism of the Brotherhood of the Rosy Cross in which were blended the doctrines and the symbolism of Christianity and alchemy.

Maier was a prodigal writer on alchemy, and his works achieved a high reputation in the unsophisticated atmosphere of the early seventeenth century. As Waite remarks, "Maier is distinguished from his peers in German alchemy by an extraordinary obscurity of style and by a passion for extensive titles." He showed no critical faculty in his writings, and his credulity was unbounded. . . . . His activities in mystical alchemy have been termed "ruinous follies," to which he sacrificed his time, fortune, reputation and health. Undoubtedly Maier wrote much portentous nonsense, but a great deal of it was at the same time erudite nonsense. He shows all the marks of a widely-read scholar of his day, and his writings abound in allusions to classical literature.[11]

Maier's works are rich in pictures, almost all of them interesting, many of them clearly symbolizing the central doctrine of alchemy; others having only a remote and far-fetched connection with it. Typical of the latter are the pictures in his *Viatorium, hoc est de Montibus Planetarum, seu Metallorum* (Traveller's Guide, or Treatise on the Mounts of the Seven Planets or Metals), 1618, the last picture of which represents a man leading a benevolent lion about an arena by means of a string around his neck—"This is the Lion, a Guest of Man; this is Man, the Lion's Physician"—and is evidently to be interpreted as meaning that gold "is put through its paces" by the alchemist. In his *Symbola Aureae Mensae Duodecim Nationum* (Symbols of the Golden Table of Twelve Nations), 1617, twelve of the heroes of alchemy, of twelve different nations, are pictured, Hermes the Egyptian, Mary the Jewess, Democritos the Greek, Morienus the Roman, etc.

[10] The Wellesley College copy is a year earlier than the earliest copy known to Professor John Read. Several of its pages are mis-numbered and there are numerous typographical errors. The engravings on pages 169 and 173 had been transposed and the error has been rectified by superimposing the correct engravings. See Read's "Prelude to Chemistry" for a full account of the book, of Michael Maier, and of his other publications.

* The translations of Maier's Epigrams which are quoted in the present article are Miss Robathan's.

† A similar experiment has been carried out by Professor John Read of St. Andrews University, Scotland, with the help of Mr. F. H. Sawyer, Lecturer in Music in the University, and with that of the University choir: see "Prelude to Chemistry," p. 281 ff. The fugues were sung at St. Andrews and at the Royal Institution in London, accompanied by lectures by Professor Read.

[11] READ, JOHN, *op. cit.*, pp. 232–3.

Avicenna the Arab is represented as watching an eagle attempt to fly away from a toad to which it is attached by a chain—the volatile Sulfur principle cannot be separated from the fixed Mercury principle when the two have entered into perfect combination—and Roger Bacon the Englishman is shown balancing the elements, Fire and Water, and awaiting "welcome gifts" in consequence of his skill.

Maier's masterpiece, *Atalanta Fugiens*, contains fifty copperplate Emblems by the famous engraver, Johannes Theodorus de Bry of Frankfurt-on-Main, at whose expense the book was printed. The title-page is handsome both in respect to the language of the title and in respect to its engravings which picture the principal

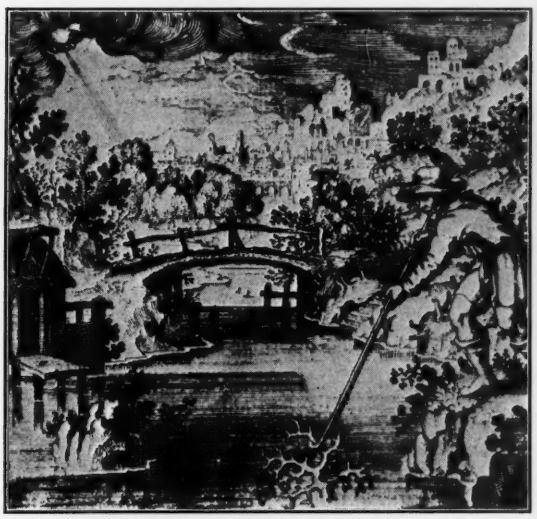

FIGURE 10

EMBLEM XXXII OF *Atalanta Fugiens*

"A sea plant growing under the water in Sicily sends forth many branches under the warm waters. Its name is coral, and it comes out harder when the North wind is sending chilly weather from a relentless sky. It becomes stone, and has a red color in its many branches. This is a fitting example of a natural stone."

Note the cold wind in the upper left-hand corner. The imagery of the picture probably amounts to this, that the Red Stone (Philosopher's Stone) results from the combination of hot and cold.

events in the story of Atalanta. This woman, the fleetest-footed of mortals, wished to marry no man, and disposed of her suitors by challenging them to race with her; she promised to marry the first man who would defeat her in the race, but all whom she defeated would be put to death. Hippomenes, who loved her, took counsel with Venus who suggested a strategem. She gave him three golden apples from the Hesperides, apples which Hercules had gathered, and these he threw down upon the course one at a time during the race. Atalanta stopped three times to gather the glittering fruit, and the consequent delay gave victory to Hippomenes. Atalanta fulfilled her promise, but the happy couple, having profaned the temple of Cybele by their embraces, had the misfortune to be metamorphosed into lions by the irritated goddess.

The notion of Atalanta fleeing perhaps gave Michael Maier the idea for his fugues in which the Atalanta or woman's voice leads or flees and the Hippomenes or

FIGURE 11

EMBLEM XLIV OF *Atalanta Fugiens*

The dismembered parts of the King (gold) after treatment in the coffin (furnace) produce the metal again, which however is not perfect, for all of the parts were not taken—"sulfur which generates sulfur is lacking." The Arabian philosopher seems to be explaining the trouble to the unsuccessful operators.

man's voice follows or pursues. Venus giving apples of gold suggests to any alchemist the production of gold from copper. This was perhaps enough to cause Michael Maier to see alchemical symbolism in the legend—certainly the symbolism is no deeper than that, no more profound that a superficial and accidental coincidence of connotations—perhaps it was this which led him in *Atalanta Fugiens* to attempt to correlate the symbolism of alchemy with the tales of classical mythology. At any rate, he did not succeed in the effort.

Many of the Emblems have no visible relation to Graeco-Roman mythology (*cf.* Figures 9, 10, and 11), and many also have only the remotest connection with alchemy. Some of them symbolize very clearly the idea that the two Prime Principles must be brought into combination or interaction for the production of gold and the Philosopher's Stone, but the same pictures commonly have no mythological relationships. Others show mythological personages or events, while the Epigrams which accompany them point out alchemical

relationships which are exceedingly tenuous. In general either the Emblem or the subjoined Epigram refers in some way either to classical mythology or to alchemy, and in general a convincing parallelism is lacking.

Emblem XXII represents a woman tending a kitchen fire, in the foreground a tub of water containing two trout, and beyond it a cat contentedly curled up on the floor, probably purring and paying no attention to the fish. The Epigram reads,

Whoever wants to accomplish much with little effort, in the face of Saturn (which is dark) sprinkle snow. And you will have a very white kind of lead. After which nothing remains except a woman's work. Then cook, as a woman, who places jars on the fire. But let the trout dissolve in their own water.

The advice to sprinkle snow in the face of Saturn is a straightforward admonition in the common language of alchemy to whiten Saturn, to transmute lead into silver. After that, only continued decoction is necessary, as the books of the alchemists insist repeatedly. The two trout evidently symbolize the two Principles which are to be cooked together until they form one homogeneous mass.

Emblem XXXI depicts a King, crown on head, swimming in the water; rocky promontories, castles, and a city in the background. He appears to be in distress and is calling for help.

A King whose crown weighs heavily upon his head is swimming over the vast sea, and in a loud voice he cries: "Why do you not bring me help? Why do you not come to my aid? If you rescue me, I can make you wealthy. Take me back to my kingdom, if you are wise; and you will suffer neither poverty nor disease.

The Emblem and Epigram appear to signify merely that gold is crying out to be saved, other Emblems having made it clear that the materials of the Philosopher's Stone are common and everywhere available.

Emblem XLV pictures the Earth, the Sun, the Moon and the heavenly bodies, the remote part of the Earth being in shadow and the shadow of the Earth being upon a part of the heavens. Its intent is evidently to emphasize that the Two Opposites, here symbolized by light and shadow, are needful for the accomplishment of the Great Work.

The Sun, the heaven's bright torch, does not penetrate thick bodies. Therefore a shadow lies on their farther parts. Although this is among the commonest of all things, yet it has brought many advantages to astronomers. But the Sun has given more gifts to the Wise, and also its shadow, since it accomplishes a task with its gold-bearing art.

The engraver of the Emblems thought well enough of them to pay for the publication of the book. Maier surely enjoyed himself in writing the Epigrams and music. A man must find delight in the work of his own hands, for that is his portion. And verily, they had their reward. And the alchemists of the seventeenth century, familiar with the fundamental doctrine of their art, no doubt found pleasure, as we may do, in the associations aroused by this same doctrine in the minds of the artistic and skilful de Bry and the erudite, imaginative, and ingenious Count Michael Maier.

The ALCHEMICAL FUGUES *in* COUNT MICHAEL MAIER'S ATALANTA FUGIENS*

HELEN JOY SLEEPER†

Assistant Professor of Music, Wellesley College, Wellesley, Massachusetts

THE Preface addressed to the Reader in the 1617 edition of *Atalanta Fugiens*, now deposited among the treasures of the Wellesley College Library, indicates something of Count Michael Maier's purpose in preparing this unique combination of alchemy, poetry, pictures, and music.

"..... For the cultivation of the intellect God has hidden limitless secrets in nature. Among these the chemical secrets are first and most precious after the divine mysteries. These secrets are to be investigated by men of a higher nature and those who are liberally educated. Since they are subtle, venerable, sacred, rare and abstruse, they must be comprehended by

* This paper accompanied one by Dr. Tenney L. Davis of the Massachusetts Institute of Technology on the subject: Count Michael Maier's Use of the Symbolism of Alchemy. They were both read at Wellesley College on March 2, 1938, with musical illustrations furnished by a group of chemistry students from Wellesley and the Massachusetts Institute of Technology who sang several of the fugues.

† Present academic title: Research Librarian in Music.

the intellect before the senses, rather through the deep contemplation of the reading of authors and a comparison of these among themselves and with the works of nature. Manual experimentation is blind without the theory which points the way.

"Next after the intellectual sciences are to be numbered those that treat of the visible and the audible, such as optics or perspective and painting, and also music, whether vocal or instrumental. . . . . In this [*i. e.*, music] the ancient philosophers were trained, and they taught that the man who refused the lyre at a banquet was to be considered uneducated. They said whoever did not enjoy musical harmony was not himself harmoniously composed. Pythagoras, who was distinguished in the same art, is said to have used the symphonies of music morning and evening

The book consists of fifty alchemical discourses, each followed by an engraved emblem and its accompanying Latin epigram, with music and a translation of the epigram into German on the opposite page. On the musical pages the melody for the voice which leads off is placed at the top and is designated "Atalanta fugiens." Next below is placed the second voice which follows, called "Hippomenes sequens"; while at the bottom is the fixed cantus, or "Pomum morans." (See Figure 1.)

In using the term *fuga* for his settings of the epigrams

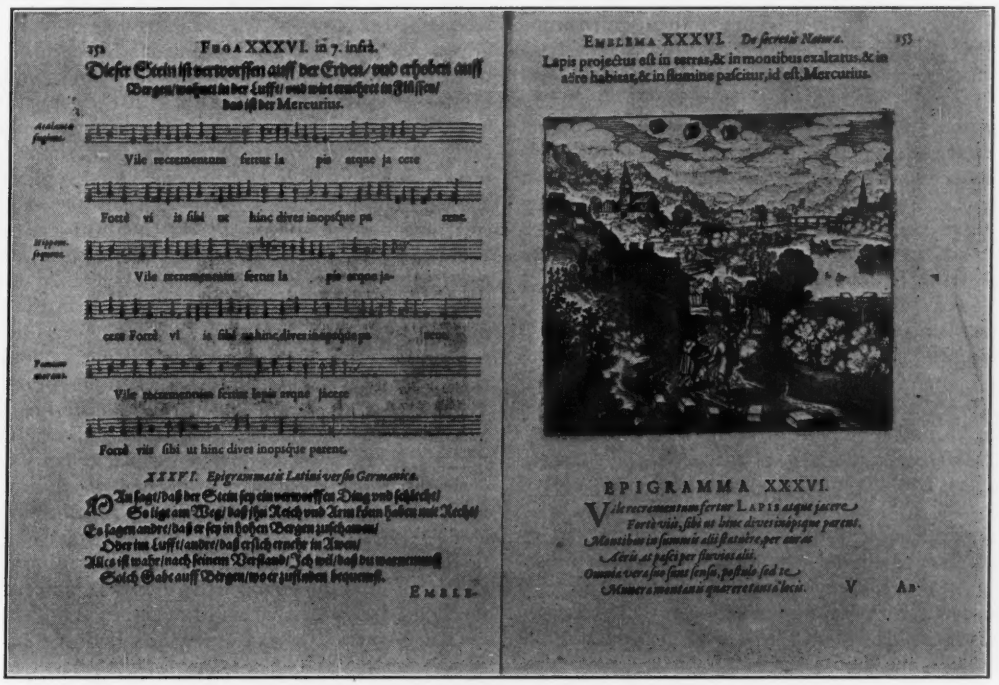
FUGA XXXVI. in 7. instr.
Dieser Stein ist geworffen auff der Erden/ und erhoben auff Bergen/ wohnet in der Lufft/ und wird empfest in Fewr/ das ist der Mercurius.
Atalanta fugiens.
Vile recrementum fertur la pis atque ja cere
Fortè vi is sibi ut hinc dives inopsque pa rente.
Hippom. sequens.
Vile recrementum fertur la pis atque ja-
cere Fortè vi is sibi ut hinc dives inopsque pa rente.
Pomum morans.
Vile recrementum fertur lapis atque jacere
Fortè vis sibi ut hinc dives inopsque parere.
XXXVI. Epigrammatis Latini versio Germanica.
Ein jeder/ daß der Stein sey ein verworffen Ding und schlecht/
So liegt am Weg/ daß jhn Arm und Reich mit Füssen tritt/
Es sagen andre/ daß er sey in hohen Bergen zuschauen/
Oder im Lufft/ andre/ daß er sich ernehr in Awen/
Alles ist wahr/ nach seinem Verstand/ Ich will/ daß du recrementum
Solch Gabe auff Bergen/ wo er zuhaben bequemst.
EMBLE-
EMBLEMA XXXVI. De secretis Naturæ. 153
Lapis projectus est in terras, & in montibus exaltatus, & in aëre habitat, & in flumine pascitur, id est, Mercurius.
EPIGRAMMA XXXVI.
Vile recrementum fertur LAPIS atque jacere
Fortè vitæ, sibi ut hinc dives inópsque parent.
Montibus in summis alii statuere, per aera
Aëris at pasci per fluvios alii.
Omnia vera suo sunt sensu, postulo sed te
Munera momentanea quærere tanta locis. V AB-

FIGURE 1

to quiet the spirits of his pupils, for this is the special power of music that it can either arouse or soothe the emotions. . . . .

"These three things, hearing, seeing and perceiving, must be put before you so that they may be embraced at one glance. We have joined the sight with the sound and the sense with the intellect in such a manner that you have at the same time and in one book spread out for your own use poetry and allegory, pictorial emblems, the most secret chemical formulae investigated by the intellect, and finally, music the more rare."*

Maier then tells the familiar myth of Atalanta and explains its relation to his fugues.

"As Atalanta flees, one musical voice always flees before another and the other one follows, just as Hippomenes. In the third, however, which is simple and of one value, they are stabilized and made firm, as if by a golden apple. . . . . .'\

* Translation prepared with the help of Miss Dorothy Robathan, Assistant Professor of Latin, Wellesley College.

in *Atalanta Fugiens*, Michael Maier appears to have deliberately retained an earlier usage for the sake of the obvious symbolic suggestion. His pieces are not fugues in the sense in which the word came to be understood in the seventeenth century. They are really canons for two voices set to a given melody, or *cantus firmus*. As late as the sixteenth century, however, composers designated the canon as *fuga per canonem* or simply *fuga*.

Canon represents the strictest form of musical imitation, in which one voice, sometimes called the *Dux*, leads off with a melody which is presently taken up by a second voice, the *Comes*, singing the same succession of tones but always maintaining its fixed distance behind the first. There may be a third, a fourth, or even more voices continuing in the same manner. The familiar round is a simple type of canon in which all the

voices sing at the same pitch, but each in turn starting a measure or so after the one immediately preceding.

The earliest historical document on canon is the famous Reading Rota of the thirteenth century, "Sumer is i-cumen in." Developing throughout the course of the fourteenth and early fifteenth centuries, this style reached a high peak of technical perfection in the late fifteenth and sixteenth centuries. Sheer delight in propounding complicated problems for the sake of solving them led the Flemish masters of the period especially to explore the possibilities of canonic writing at every interval. The *Comes*, instead of imitating the *Dux* at the same pitch, might sing the melody a fifth, or third, or ninth higher, or a fourth, sixth, or seventh lower, as the case might be. These indefatigable composers invented further difficulties for themselves. Thus *Comes* might be asked to sing the melody announced by *Dux* upside down (inverse canon), or backward (retrograde canon), or both upside down and backward at the same time. Or, again, the note values of the second voice might be twice as long as those of the first, or, conversely, one-half or one-third as long. Most complicated of all were the puzzle canons in which the composer wrote down but a single voice part, adding a cryptic Latin motto, which, if its meaning could be divined, gave a clue to the second singer as to when he should start his imitation, at what interval, and in what direction. Technical resource in the manipulation of all possible combinations of a melody with itself was developed to a point of virtuosity that established a standard for all time. In the hands of a Josquin Despres or a Palestrina it was used with a freedom so absolute that it could be made to serve expressive ends as well.

It was perhaps inevitable that display of mere technical contrivance should eventually be carried to excess. Burney[1] neatly classifies as "canonists" such learned seventeenth century composers as Francesco Soriano, who published a collection of one hundred and ten canons on the hymn *Ave Maris Stella*,[2] and Pietro Francesco Valentini, whose canon to the words *Illos tuos misericordes oculos* was capable of more than two thousand resolutions.[3]

An understanding of Maier's canons necessitates brief consideration of the important principle of *cantus prius factus*, or the song already made. Throughout the medieval period, the art of composition laid much less stress on the invention of original melody than on the exercise of skill in showing what could be done with a melody already in existence, in the way of adding other appropriate melodies to go with it. The given tune, or *cantus firmus*, might be a liturgical chant or a familiar popular song. It might be used as the sustaining lowest voice, called for that reason the tenor, or in an ornamented form it might furnish the principal top melody. Again, short fragments or motives from it might be passed about from voice to voice in free imitation. Sometimes its notes were so greatly lengthened that it was no longer recognizable as a continuous melody. Sometimes it was so submerged in the midst of a complicated web of tonal lines that it really could not be distinguished; but still it was always there, holding the composition together and providing a firm structural basis.

The late sixteenth and early seventeenth centuries saw the application of this older principle of *cantus prius factus* to the more recently acquired canonic technic. In other words, the composer voluntarily imposed a further restriction on his freedom of movement. Not only must his voices move in scientifically exact relationship to each other, but they must also fit in with a given cantus. It is difficult to find any large body of compositions in this severely circumscribed form. It seems to have been cultivated somewhat by the German organists who had at their disposal a considerable body of new canti in the Lutheran chorale tunes, and whose sets of variations on these tunes occasionally contained a canon written against the chorale. One hazards a guess that this form of exercise may have formed part of the training for students of composition to develop facility in writing. This theory is borne out by the appearance of examples of canon set to Gregorian as well as Lutheran chorale melodies in Sweelinck's *Rules of Composition* and in Scheidt's *Tabulatura Nova*, both early seventeenth century works.[4]

Count Michael Maier, as a highly educated and widely traveled man with varied cultural interests, could hardly have failed to come in contact with some of this music. The imperial court as well as the city of Prague maintained a worthy musical tradition. The nomination to the position of chamber organists of the noted brothers Hassler, Hans Leo and Jacob, in the decade immediately preceding Maier's court appointment, bears witness to this fact. The influence of Jacob Handl, called Gallus, prolific composer and famous cantor of the church of St. Johann am Ufer, must still have been felt. Maier's retirement to Magdeburg on Rudolph's death, and his subsequent journeyings about Germany placed him in the center of a region in which nearly every small court and city could boast an organist of more or less competence busy turning out chorale arrangements.

The canons in *Atalanta Fugiens* are remarkable in that all fifty are set to the same cantus,[5] thus levying a tax on the ingenuity of the composer of a kind offering

[1] BURNEY, SIR CHARLES, *"A general history of music,"* London, **1776–89.** Ed. by Frank Mercer, 1935. Vol. II, pp. 412–6.

[2] "Canoni, et Oblighi di centi et dieci sorte sopra l'Ave Maris Stella a 3, 4, 5, 6, 7, et 8 voci." Roma, **1610.** (Cited in EITNER, R., "Quellen-Lexikon," 10 vols., IX, 210, **1903.**)

[3] "Illos tuos misericordes oculos ad nos converte. Canone . . . con le sue Resolutioni in più di Duemilia Modi . . .," Roma, **1629.** (EITNER, R., *op. cit.*, X, 25.)

[4] SWEELINCK, JAN PIETERSZOON, "Werken," Leipzig, **1901,** X, 72–7. SCHEIDT, SAMUEL, *"Tabulatura Nova,"* in *Denkmäler Deutscher Tonkunst*, I, 78–83, 187, 201, 214.

[5] F. H. Sawyer in a note on the music of "Atalanta Fugiens" appended to JOHN READ'S "Prelude to chemistry" (The Macmillan Co., New York City, **1937,** p. 282) suggests that "this theme may be a varied form of some tune having alchemical associations, and the fact of its constant use may be taken as symbolical of the elusive formula for which the alchemist ceaselessly sought."

few parallels in the history of music. They exhibit considerable variety of melodic invention, and furnish examples of most of the kinds of canon already mentioned. The first forty are simple direct canons involving imitation at all the intervals above and below the starting note of the "Atalanta" voice. (See Figure 2.) The cantus is placed about equally in the position of lowest, middle, and highest voice. Beginning with the forty-first, the more complicated varieties are attempted. In two of them, merely the words of one voice are printed upside down; in two, inverse canon

FUGA XXXVI
LAPIS PROJECTUS EST IN TERRAS
Vi- le re- cre- men- tum fer- tur
Vi- le re- cre-men-tum fer- tur la-
Vi- le re- cre-men-tum fer- tur
la- pis at- que ja- ce- re For- tè vi- is
pis at- que ja-ce- re For-tè vi- is si-
la- pis at- que ja-ce- re For-tè vi-
si- bi ut hinc di- ves in- ops- que pa- rent.
bi ut hinc di-ves in-ops- que pa- rent.
is si-bi ut hinc di-ves in-ops- que pa- rent.

FIGURE 2

appears; in one, the cantus is sung backward; in another, backward and inverted at the same time; in three, there are rhythmical variations. In one of the latter, the "Hippomenes" voice doubles the value of the notes in the "Atalanta" voice; while in another, the note values are reduced to one-third.

In estimating the worth of this music, one must concede at the outset that Maier's ingenuity of idea and persistence of effort unfortunately outran his technical musical skill. Just as with the experiments of the alchemists, the attempted canons frequently meet with disaster. In fact, the number of those reasonably free from the most flagrant of contrapuntal faults is relatively few, comprising approximately but a quarter of the entire fifty. Maier shows himself to be the scientist rather than the musician in the impartiality with which he is willing to put on record the unsuccessful as well as the successful experiments.

Although the use of familiar liturgical or popular melodies as a basis for new compositions was a method universally practiced from the twelfth century until well into the eighteenth, composers were frequently casual about acknowledging the sources of this borrowed material. Probably in most instances where the name does not appear, such labeling would have seemed superfluous, since the canti would naturally have been well known to a contemporary public. Michael Maier doubtless had no intention of providing an element of

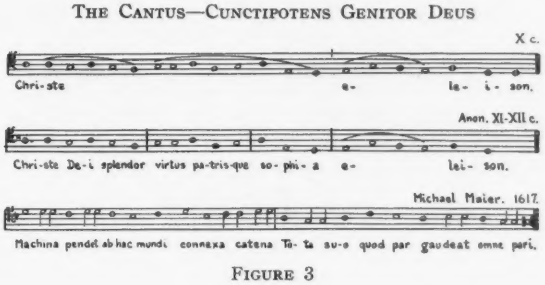
THE CANTUS—CUNCTIPOTENS GENITOR DEUS
X c.
Chri-ste e- la- i- son.
Anon. XI-XII c.
Chri-ste De-i splendor virtus pa-tris-que so-phi-a e- lei- son.
Michael Maier. 1617.
Machina pendet ab hac mundi connexa catena Te- te au-e quod par gaudeat omne pari.

FIGURE 3

mystery in neglecting to identify his "delaying" voice. Search for its source at first presented an aspect comparable to that of the proverbial needle in the haystack. Might it be some phrase from an ecclesiastical chant (the *Liber Usualis* contains approximately eighteen hundred), or from a Lutheran chorale, or from an old popular tune? The cantus was obviously much older than the seventeenth century, and, moreover, could be analyzed as written in the scale known as the first church mode. A somewhat idle and none too hopeful glancing through the first mode chants in the *Liber Usualis*[6] brought unexpected results, when the melody suddenly appeared embedded in the midst of the Kyrie *Cunctipotens Genitor Deus* as the second phrase, set to the text *Christe eleison*. (See Figure 3.) In choosing this particular chant Maier was thus simply using one of the most familiar of church melodies, and one, moreover, employed by composers from an anonymous eleventh or twelfth century writer to Frescobaldi in the seventeenth century.[7]

[6] "The Liber Usualis" with introduction and rubrics in English. Desclée & Cie, Tournai, **1934**, p. 25.

[7] Other works using the cantus *Cunctipotens Genitor Deus* are:
ANON., XI–XII Cent. Organum. In Coussemaker. *L'Histoire de* l'Harmonie au Moyen Age, **1852**, p. 226. See also SCHERING, ARNOLD, *Geschichte der Musik in Beispielen*, **1930**, p. 6.
ANON., XV Cent. Kyrie from the Trent Codices. In *Denkmäler der* Tonkunst in Österreich, XXXI, **1934**, p. 62.
FRESCOBALDI, *Fiori Musicali*, **1635**. Ed. Senart, Paris, **1932**, pp. 32–7.
PALESTRINA, Missa *In Minoribus Duplicibus*. *Werke*, XXIII, 26.
ROKSETH, YVONNE, ed. *Deux Livres d'Orgues parus chez Pierre Attaingnant en* **1531**. *In Publications de la Société Française de Musicologie*, I, **1925**, p. 20.

A natural question arises as to whether Maier made any discoverable attempt to suit melody and text appropriately in this highly artificial scheme. Examination of the canons reveals certain clearly intended relationships between the music and the words.

From the standpoint of meter, there is a definite correspondence between the cantus and the epigrams. Maier's epigrams are written in elegiac stanza form with terms by means of an inverse canon, in which every ascending interval of the first voice is imitated by a corresponding descent in the second, and *vice versa*, and the words of one voice are printed upside down. Or again, Emblem XLVI represents Jupiter dispatching two eagles to fly to the ends of the earth, one toward the East and the other toward the West. (See Figure 4.) In the accompanying canon, directions are given for the

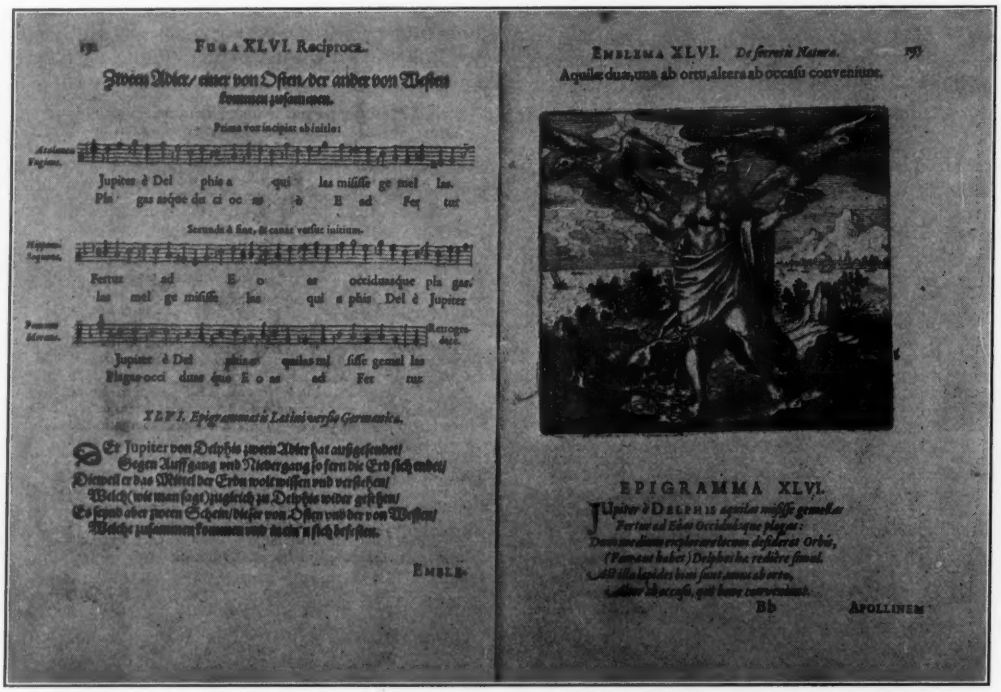
Fuga XLVI. Reciproca.
Zween Adler/ einer von Osten/ der ander von Westen kommen zusammen.
Prima vox incipit ab initio:
Jupiter à Del phis a qui las mississe ge mel las.
Pla gas aeque de ci oc as à E ad Fer tur
Secunda à fine, et canat versus initium.
Fertur ad E o as occidasque pla gas
las mel ge missis las qui a phis Del è Jupiter
Jupiter è Del phis a qui las mississe gemel las
Plagas occi dasque E o as ad Fer tur
XLVI. Epigramma in Latini versus Germanica.
Er Jupiter von Delphis zween Adler hat außgesendet/
Gegen Auffgang und Niedergang so fern die Erd sich endet/
Dieweil er das Mittel der Erden wolt wissen und verstehen/
Welch (wie man sagt) zugleich zu Delphis wider geht zusammen/
Es seynd aber zween Schein/ dieser von Osten und der von Westen/
Welche zusammen kommen und sich in sich beschliessen.
EMBLE
Emblema XLVI. De secreto Naturæ.
Aquilæ duæ, una ab ortu, altera ab occasu conveniunt.
EPIGRAMMA XLVI.
Jupiter è Delphis aquilas missit gemellas
Fortes ad Eoas Occiduasque plagas:
Dum medium explorare orbem desiderat Orbis,
(Fama est habet) Delphos hic redire simul.
Ast illæ lapides bini sunt amnes ab ortu,
Alter ab occasu, qui hanc convenient.
Bb
APOLLINEM

FIGURE 4

alternating hexameter and pentameter lines. The long and short syllables of the couplets find an almost exact parallel in the arrangement of the whole and half notes in the cantus. The pair of short syllables in the dactyllic foot is invariably accompanied by the division of the corresponding whole note of the cantus into two half notes. The only exceptions to perfect musical scansion of the Latin verses are two small ones; *viz.*, at points where a syllable would be elided in reading, a note is provided for singing; and the ends of the hexameter lines, which may be either a spondee or a trochee, regularly are translated by two shorts, in order not to interrupt the uniform flow of the tones of the cantus.

From the standpoint of expression of the meaning of the text, Maier has shown ingenuity in adapting the customary canonic devices to the symbolism of his emblems. Thus, for example, the idea of the shadow cast by the sun, in Emblem XLV, is translated into musical *Dux* to start at the beginning and proceed to the end, while the *Comes* starts the same melody at the same time from the end and sings toward the beginning. The dismembered body of a king shown in Emblem XLIV* finds its musical counterpart in the breaking up of the long even notes of the first voice into the quarters and eighths of the second.

The association of epigrams and music in *Atalanta Fugiens* emerges as singularly appropriate in one final aspect. In selecting the verse form of the elegiac couplet, and a quantitative rather than an accentual rhythm, Michael Maier allies himself with those Renaissance scholars and poets who, in their revival of the study of Greek literature, made use of classic meters for their own writings. In selecting the type of musical setting for these stanzas, he chooses the most scientifically exacting form of composition devised by the

* *Cf.* DAVIS, T. L., "Count Michael Maier's use of the symbolism of alchemy," J. CHEM. EDUC., **15**, 409 (1938).

learned contrapuntists of the fifteenth and sixteenth centuries, binding himself further by the necessity of producing fifty different canons to the same cantus. The union of these two elements might reasonably be interpreted as one more symbolic demonstration of his main thesis; namely, the affinity between certain manifestations of antique culture and certain products of medieval science.

SOME EXPERIENCES *in* TEACHING GENERAL CHEMISTRY *to* ARTS STUDENTS *for* ITS CULTURAL VALUE*

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INTRODUCTION

THE case for a special course in general chemistry for the non-professional or liberal arts student seems to be well established. The discussions and experiences of the various teachers in the bibliography appended testify to this fact. While there is fairly good agreement as to the objectives of such a course (*9*), there are differences as to their relative importance and methods of attaining them. Local conditions in the colleges and universities, individual differences in teachers, variations in the size of classes, and the heterogeneity of students in background and training explain most of these discrepancies. Instead of interpreting this apparently controversial situation as discouraging the author feels that it is wholesome. The important observation is that the idea is growing.

It is not the object of this paper to enter into a discussion of the historical development of this special course or to discuss its merits or educational needs, but rather to relate some of our own experiences.

The coöperative plan of education as applying to all departments of the liberal arts college is completing its sixteenth year at Antioch College. The program aims at the symmetry of a rounded cultural training and hopes "to bring about a balanced development of character, intelligence, and power; to correct prevailing disproportionate emphasis upon elements of personality or of environment; to give the student a liberal college education, vocational training, and apprenticeship to practical life."

For the realization of this objective it was apparent early that all students should have, among other things, an intelligent understanding of the physical and biological sciences. In particular, it was felt that in this chemical age, a knowledge of general chemistry is just as essential to a liberal education as many of the time-honored required courses in the humanities.

The organization of a required chemistry course for arts students at Antioch must recognize the conditions peculiar to the coöperative plan. Under this plan the student body is divided into Division A and Division B; two students, one from each division, share a co-operative job in some industrial or commercial organization, and alternate on five- or ten-week shifts between the campus and the job. The academic year is forty weeks long, twenty for each division. Chemical education as it existed at Antioch in 1931 has been discussed by W. A. Hammond and D. S. Hanchett (*18*).

Our experience in teaching chemistry during the past fifteen years to arts students for its cultural value is divided into three distinct periods; (*a*) Cultural Chemistry, 1922–1931; (*b*) Matter and Energy, 1931–1936; (*c*) General Chemistry, 1936–1937.

CULTURAL CHEMISTRY

A special course in general chemistry for liberal arts students was organized in the fall of 1922. For want of a better name it was called "Cultural Chemistry." The author presented his experience with this course in a paper entitled, "A Cultural Course in Chemistry" read before the Division of Chemical Education at Los Angeles, August 7, 1925.† It was later published in

* Presented before the Division of Chemical Education at the ninety-third meeting of the A. C. S., Chapel Hill, N. C., April 13, 1937.

†Dr. Bancroft's paper (*5*) has been cited (*22*) as the pioneer paper on the subject of cultural chemistry, although it appeared the year following the author's paper. In a letter written to the author, May 2, 1926, Dr. Bancroft expressed his regrets at the oversight in failing to mention the author's paper in his own. According to Timm (*22*) Dr. Boltwood of Yale College organized a course in general chemistry for liberal arts students about the same time the author began his course. There is no record, to the author's knowledge, that Dr. Boltwood published his experience with this course. Others have undoubtedly experimented with its possibilities at an even earlier date.

the JOURNAL OF CHEMICAL EDUCATION under a different title. The author's paper and that of Dr. Hammond and Dr. Hanchett relate fairly adequately our experience with cultural chemistry during the first period.

MATTER AND ENERGY

The change from a separate course in cultural chemistry to a combined orientation course in physics and chemistry was made for the following reasons:

(1) The pressure of our growing required-course program was necessitating the combination of some courses in order to economize the students' time for their chosen fields of concentration.

(2) The possibility of integrating physics and chemistry, *i. e.*, amalgamating or combining the subject matter into a unified whole was inviting and challenging. It would eliminate a certain amount of overlapping and duplication of subject matter. It would assist the senior students in their comprehensive examinations. A part of this comprehensive examination is devoted to the physical sciences; the questions have their basis in this field but have implications in other fields covered by the required-course program.

(3) It would bring the physics and chemistry departments closer together at a time when the present tendency in most colleges is to keep them apart. The chemistry and physics teachers, sharing the course, have an opportunity of understanding and appreciating the others' problems and points of view. The necessity for coöperation between the departments of physics and chemistry and between chemistry and the other physical and biological sciences is growing more important with the increasing specialization of the teachers. This is particularly important if any integration is to be successfully achieved with these sciences.

The Matter and Energy course was first given in the fall of 1931. During the first two years the course was organized and managed by Dr. G. E. Owen of our physics department. Members of the chemistry department were invited to give lectures on selected subjects. The students met in separate laboratories for experimental work in physics and chemistry. There were three lectures, one discussion section, and one three-hour laboratory period a week. A detailed syllabus of the course defining the responsibilities, purpose, conduct of course, and assignments was given to each student.

After two years of pioneering, it was apparent that the course needed the influence and balance of more chemistry. The responsibility for reorganizing it was shared with Dr. Owen by Dr. Austin M. Patterson and the author. Much of Dr. Owen's original approach to the problem was retained.

As the result of receiving many inquiries, and at the risk of amplifying this paper, the author believes that some detailed information about our experience with this course may be justified.

Exemptions.—Waiving examinations were given at the beginning of each year for those with previous experience in high-school chemistry, physics, or both. Those who passed in both subjects were excused; those who passed either one were permitted to devote most of their time to the other.

The purposes of the course as outlined in the syllabus were:

(1) To develop an appreciation of the scientific procedure as it has been used in deriving and testing the fundamental theories and laws of the physical sciences; that is, of the way in which information is collected and classified, of the process of analysis or reduction to simpler terms, of the setting up, testing, and modification of one hypothesis after another until finally a general formula or law of nature is discovered.

(2) To make the student familiar with fundamental physical and chemical concepts, certain general laws and principles, and a large number of phenomena and experiments, to show the applications of this knowledge to the development of natural resources, to the problems of industry, and to those of the daily life of the individual.

(3) To develop the ability to think in the domain of physics and chemistry.

(4) To trace the historical development of thought and discovery in the physical sciences and to relate it to philosophical, social, and economic development.

(5) To acquaint the student with the tools and apparatus of the physics and chemistry laboratory, so that he may see for himself how observations of various kinds are made, what precautions are taken, what difficulties present themselves, and what technics are required, and that he may learn to judge for himself what are the limits of accuracy of the experimental observations.

The *technical requirements* of the course, as outlined in the syllabus were:

(1) "Class attendance is compulsory."

(2) "You are expected to perform the laboratory experiments scheduled. Laboratory work during the second semester is optional."

(3) "Read at least one book from the required reading list each semester and write a report on it."

(4) "Write one paper each division on a subject to be chosen by you and approved by the instructor. Papers must conform to the standard of English themes."

(5) "The complete record of your work will be kept by you in a *loose-leaf Notebook** and may include, in addition to the book reports and division papers, lecture notes, short themes, abstracts or articles read in current magazines or newspapers; incidents from the lives of famous physical scientists; a diary of the work you do in the course and the time devoted to it; clippings, pictures, and puzzles; a report of visits to industrial plants; reports of new applications of science. You are not restricted as to what you may put in this book."

Laboratory work.—The students alternated in their laboratory work between chemistry and physics. The first semester's work in chemistry was required and

* We wish to stress the importance of this Notebook by capitalizing it throughout the paper.

consisted of modified conventional experiments. The laboratory work in the second semester was optional. Since a large percentage of the class consisted of women, experiments selected from "Chemistry Applied to Home and Community," by Beery, were profitable and created much interest. Experiments taken from the fourth edition of "Emulsions," published by Carbide and Carbon Chemicals Corporation, and from "The Chemical Formulary" were also instructive. The chemistry of the various reactions and the significance of the various constituents in these experiments were explained.

The purpose of the experiments in the physics laboratory was to make the students familiar with the tools of the physicist and methods of interpreting data, and to teach a few simple skills applicable in daily life. Assistants performed the more difficult experiments with the coöperation of small groups. Experiments were made in photography and in the use of electrical appliances; the current, voltage, and power of lamps, irons, and toasters were measured; fuses were blown and replaced, and prices of operation were figured. Musical instruments were studied. The stretching of a copper wire, introducing the use of the optical lever, gave opportunity for plotting and interpreting curves and demonstrated some of the engineering properties of materials. Each student made a simple motor, made it operate, and took it away with him. The motor parts are purchased for about fifteen cents.

Students who elected to waive the laboratory work during the second semester were given additional outside general reading or were permitted to explore their interests in restricted fields. The evidence of this outside work was recorded in their Notebooks.

Lectures.—The subjects of the lectures in the order given were as follows. *First semester:* The Place of Physical Sciences in Modern Civilization; The Nature of Matter; The Nature of Energy, Gases; Oxygen and Hydrogen; Water (two lectures); Properties of Liquids; Properties of Solids; The Fundamentals of Mechanics; Atoms and Molecules; The Periodic Law; The Atmosphere; Nitrogen and Its Compounds; Combustion; Heat and Thermodynamics; The Halogens and Sulfur; The Nature of Waves; Musical Sounds. *Second semester:* Metals and Metallurgy; Acids, Bases, and Salts; Simple Optics; The Nature of Light; Spectra and Colors; Elementary Electrical and Magnetic Phenomena; Electric Currents and Power; Solutions; Electrolytes and Ionization; Colloidal Solutions; Liquid-Air Demonstration; Organic Chemistry (two lectures); Fats, Oils, and Soaps; Atomic Structure (two lectures); Iron and Steel; Radioactivity; Cosmic Rays; X-Rays and Crystal Structure; The Theory of Relativity; Pure and Applied Research. (Industrial men and specialists were invited in to give lectures on this last topic.) The lectures were always supplemented with as many demonstrations as practicable.

Other Features.—The textbooks used were "The Development of Physical Thought," by Loeb and Adams, and "An Introduction to Chemistry," by Timm.

A list of some thirty-five periodicals and popular books was included in the syllabus to give the student a rather wide selection of reference material.

At the end of each five-week period a twenty-minute private conference was scheduled with each student to discuss the Notebook, vocational interests, difficulties, and so forth.

No examinations were given in the course. The grade was based on the Notebook, laboratory record, attendance, conferences, and attitude.

Five field trips to near-by industries were scheduled. These took the place of five laboratory periods.

Results.—At the end of the school year of 1934, a questionnaire was submitted to a class of sixty students, requesting their impressions of the material covered in the lectures of the second semester, and the general organization of the course. The questionnaire was divided into two parts. The first part asked the students to check one or more of the following statements respecting the lectures: (1) I do not remember much about it, (2) repetition of high-school work, (3) not specific enough, (4) too technical, (5) introduced me to new material, (6) interesting. The second part of the questionnaire invited the students to offer suggestions for improving the course.

While it is obvious that many variables enter into the analysis of the results of such a questionnaire, they did give some qualitative information.

(1) The students remembered the lecture on "Metals and Metallurgy" the least; "Acids, Bases and Salts," and "Solutions and Electrolytes," showed the greatest repetition of high-school work; "X-Rays and Crystal Structure" and "Research" proved to be too general; "Cosmic Rays" proved too technical; "Spectra and Colors," "Radioactivity," and "Cosmic Rays" introduced the most students to new material, although it was gratifying to find that most of the lectures ran high on this point; "Fats, Oils, and Soaps," Radioactivity," "Atomic Structure," "Liquid Air," "Colloids," and "Spectra and Colors" were the most interesting. Again it was gratifying to find that most of the lectures scheduled proved to be interesting.

(2) With the aid of the comments of the students on the second part we make this summary:

(*a*) Features which the students appreciated:

(1) The freedom of the course is the most valuable feature; it offers possibilities for exploration of subjects of interest to the student. They enjoyed the outside reading and popular books. The history of science and biographical sketches were particularly interesting.

(2) "No examinations" helps to remove the fear of physics and chemistry, facilitating a sympathetic response to the subject and a natural approach to arousing interest.

(3) The field trips should be continued.

(4) The student private conferences were very beneficial.

(5) The privilege of dropping the laboratory work

during the second semester should be retained, since some students find the work during the first semester unprofitable. (Ninety per cent. of the students wanted the optional laboratory work the second semester. At Yale, Timm reports that forty out of three hundred students elected the optional laboratory course (*22*).)

(6) They favored the use of a textbook.

(7) They favored retaining the discussion groups.

(8) The "Notebook" in which the record of the course was kept found favor with the students.

(9) Problems, chemical equations, and similar technical details should not be stressed for cultural students.

(*b*) Objections

(1) The course lacked integration; it was a conglomeration of physics and chemistry. The unification expected was not achieved.

(2) Five credit hours out of the arts student's schedule during the freshman year appeared too much. Students with previous high-school physics or chemistry in particular objected to this.

(3) Students who became interested in chemistry and wished to continue the subject could not do so without loss of time. This was not true of the students in the former "Cultural Course" who showed any ability.

(4) The course was not economical of the instructor's time. This is an important factor in this day of reduced departmental budgets.

(5) No single adequate textbook has been developed to present the subject matter of such a combined course.

(6) Too much freedom in the choice of laboratory work resulted, at times, in too much confusion and inability of the laboratory assistants to handle the situation.

(7) There was a tendency to deal with the subject matter too superficially.

GENERAL CHEMISTRY

In 1936 the Matter and Energy course was discontinued, owing largely to the objections raised above and conditions limited by our department facilities. We now have again two separate courses in physics and chemistry required of arts students. The chemistry course is called General Chemistry in contradistinction to Inorganic Chemistry, the freshman course for technical students.

For economic and experimental reasons, we are having the students in General Chemistry and Inorganic Chemistry meet together twice a week for lectures. The lectures are prepared to meet the level of intelligence of the students in Inorganic Chemistry. A few arts students like this technical approach and even develop a professional interest in chemistry. Each course has its own syllabus outlining the students' responsibilities.

The General Chemistry course allows the students three credits (two lectures and one three-hour laboratory period each week). The laboratory work covers conventional experiments the first semester and is optional the second.

We are retaining many of those features of the Matter and Energy course which found favor with the students, namely, the looseleaf Notebook, book reports, journal articles, field trips, and the freedom to explore subjects of interest. Although the arts students listen to the somewhat technical lectures, we do not stress problems or equations. The history and philosophy of chemistry are featured. Examinations are given at the end of each semester but the author feels at present that he will eliminate this feature next year.

We are using two textbooks; a high-school book, "Chemistry for Today," by McPherson, and "An Introduction to Chemistry," by Timm. So far this appears to be a happy combination. The students purchase the former, and a dozen copies of the latter are kept on the reserve shelf in the science library. Regular weekly assignments in these books are given. The "Thought Questions" at the end of chapters in "Chemistry for Today" are answered and recorded in the Notebooks. The lectures supplemented from the references are also recorded in this book.

It is much too early to appraise or evaluate the results of this new arrangement. The author prefers to hold his judgment of the merits of this course in abeyance until the present experiment has had a fair trial.

DISCUSSION

With the growing recognition that an intelligent understanding of the physical and biological sciences is a necessary part of a general education we can expect to see more colleges and universities introducing special courses to meet this need. The pressure from the required course program of the arts student will make it necessary, in many cases, to consider the combination of cultural chemistry and cultural physics into a single orientation course.

An orientation course in chemistry and physics has much to commend it. The close relationship between chemistry and physics should make the unified treatment of these subjects ideal. The practical difficulties do not appear to be insuperable. The long traditions of teaching chemistry and physics separately, together with the highly specialized training which our modern chemistry and physics teachers receive in their graduate work, their inadequate background in appreciation of art, literature, history, sociology, economics, and philosophy, makes combinations of these courses difficult. Such courses really need a specially trained person, who not only has a broad background in the humanities but who is equally interested in both physics and chemistry and enthusiastic about teaching them together. The different outlook of the arts student necessitates a different approach. While there are some advantages in having a physicist and a chemist collaborate on such a combined course, it will invariably be a conglomeration and lack the integration

that may be achieved if one person, specially trained to see the problem as a whole, teaches the course.

Reasons why the Matter and Energy course was discontinued at Antioch in addition to the difficulties mentioned above are the extra time required for collaboration; the lack of previous experience in teaching such a course; our lack of a person who could devote most of his time to teaching it alone; and the fact that the size and resources of Antioch do not warrant us in giving the courses both combined and singly at the same time.

In the author's opinion the various criticisms launched against these special courses for arts students, namely, that they are "superficial," that "they are doomed to failure for the simple reason that they attempt too much for the time available," that they involve "teaching as little as possible about as much as possible in the least possible time," are not valid. True, the time is always too short to do the job the teacher has in mind, but our experience indicates that such courses are decidedly worth while. If the student's interest and curiosity have been aroused and he has caught the spirit of the history and philosophy of the science, the chances are good that he will continue his reading in after years.

A by-product of our experience which deserves special emphasis is the Notebook idea described above. No two of these Notebooks were alike. They showed individuality. They permitted the student to express his own interests, impressions, and reactions. The students took pride in their books and treasured them. They had something tangible to carry away as evidence of their class and reference work.

The separation of the conventional freshman course in college chemistry into one for arts students and one for professional students has other advantages. It permits the organization of the latter to suit the needs of a more homogeneous group of technically minded students. More drill in problems, equations, theory, and technical data can be introduced.

This brings up a question which has interested the author for some time. The names applied to these special courses, namely "Cultural" or "Pandemic," do not seem appropriate. They were "catchy" and have served their purpose in calling attention to these special courses. They permit the technical freshman course to be organized to meet the needs of the professional student. Since this latter course places predominant emphasis on the chemistry of inorganic compounds, why not call it "Inorganic Chemistry?" We can then reserve the expression "General Chemistry" for the special course for, after all, isn't it essentially a *general* survey of chemistry?

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The all-round liberally-educated man, from Palaeolithic times to the time when the earth shall become a cold cinder, will always be the same, namely, the man who follows his standards of truth and beauty, who employs his learning and observation, his reason, his expression, for purposes of production, that is, to add something of his own to the stock of the world's ideas.—H. F. OSBORN

The IOWA SYSTEM *of* QUALITATIVE ANALYSIS *without* HYDROGEN SULFIDE*,†

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WE WERE prompted to undertake a study of ways and means that might be used to decrease or eliminate the use of hydrogen sulfide in our freshman laboratories of qualitative analysis both for the sake of our own comfort and for the sake of the comfort of our colleagues and neighbors who objected to the hydrogen sulfide laden fumes that not infrequently drifted to their offices and research rooms. We considered semimicro qualitative analysis as a solution of our problem but were deterred in adopting it because we lacked both the necessary special apparatus and the suitably qualified instructional staff needed to initiate such a plan in classes that aggregate about five hundred students annually. Further, semimicro qualitative analysis was not as well developed in this country in 1932, when we began our search, as it is today. Even today we do not know of many large classes in freshman qualitative analysis that are using semimicro methods. So we turned to non-hydrogen sulfide systems as a possible source of relief. Our search in the literature yielded the references shown at the end of this paper. It also showed that dissatisfaction with hydrogen sulfide as well as attempts at formulating non-hydrogen sulfide systems are not new phenomena. Himly (*8*) in 1842 speaks of hydrogen sulfide as "a headache-producing stench" and proposes sodium thiosulfate as a substitute for hydrogen sulfide in qualitative analysis. During the past five years we have formulated in mimeographed books seven different systems of non-hydrogen sulfide qualitative analysis and tried them in our classes. The latest of these systems, which we call the "Iowa System" as a distinguishing name, has been used during one semester with a class of three hundred students with reasonably satisfactory results. The remainder of this paper contains a historical review of the subject of qualitatve analysis, a general discussion of non-hydrogen sulfide systems, and an outline of the Iowa System in its current form.

HISTORICAL REVIEW

We found that the classical, widely used hydrogen sulfide system of qualitative analysis is due to Fresenius, who formulated it as a self-imposed task while he was a student at Bonn University. The first edition of the Fresenius Qualitative Analysis was published in 1840 when the author was only twenty-two years old. The wide acceptance of this system by chemists throughout the world during nearly a century is a testimony of general excellence. The weaknesses of the Fresenius system are too widely known to warrant comment. In an oral communication, Professor F. B. Dains of the University of Kansas stated that fairly well-formulated schemes of qualitative analysis were currently found in textbooks for the year 1800 and that the effort of Fresenius in 1840 represented only selection from and refinement of previous schemes. We find this observation applies also to the subsequent literature of qualitative analysis of both the hydrogen sulfide and non-hydrogen sulfide kinds. The same ideas and procedures are met time after time in slightly or greatly modified forms and combinations. Broadly speaking, there are a limited number of stock procedures, none of them new, from which the would-be author of a system of qualitative analysis can form his system. His success is largely measured by his skill at selecting, arranging, and refining stock procedures.

NON-HYDROGEN SULFIDE SYSTEMS REVIEWED

The bibliography placed at the end of this paper shows that more than a score of non-hydrogen sulfide systems have been proposed. These non-hydrogen sulfide systems may be grouped in two general classes: first, those systems that eliminate the use of hydrogen sulfide gas as a reagent, but use sulfide ion from some other source such as the alkali sulfides, thiosulfate, or thioacetate (*3, 4, 6, 7, 8, 17, 19, 20, 21, 23, 24, 25, 26, 27*), and second, those systems that dispense with the use of sulfide ion completely or nearly so (*1, 2, 5, 9, 10, 11, 12, 14, 15, 18*).

The first two of the seven non-hydrogen sulfide systems tried by us were of the type that dispensed with the use of sulfide ion. The central and critical point of most systems in this category is a procedure in which certain amphoteric and non-amphoteric metallic ions are separated in a strongly alkaline solution with or without the help of peroxide. Our experience indicates that separations in alkaline solutions are frequently

* Presented as a part of the symposium on Qualitative Analysis before the Division of Chemical Education at the Fourteenth Midwest Regional Meeting of the A. C. S., Omaha, Nebraska, April 29, 30, and May 1, 1937.

† The author reserves the right to publication in book form.

neither sharp nor complete. In many instances ions such as copper, cobalt, and manganese are not completely precipitated as hydroxides. Difficulty is met in the analysis of mercury, arsenic, antimony, and tin if the use of sulfide ion is eliminated. We were unable to find or formulate a system of this type that was not subject to these objections.

Turning to systems that use thioacetate, thiosulfate, or alkali sulfide as a source of sulfide ion, we did not give thioacetate systems serious consideration because the cost of this reagent is too great to permit its use with large classes. At first sight sodium thiosulfate

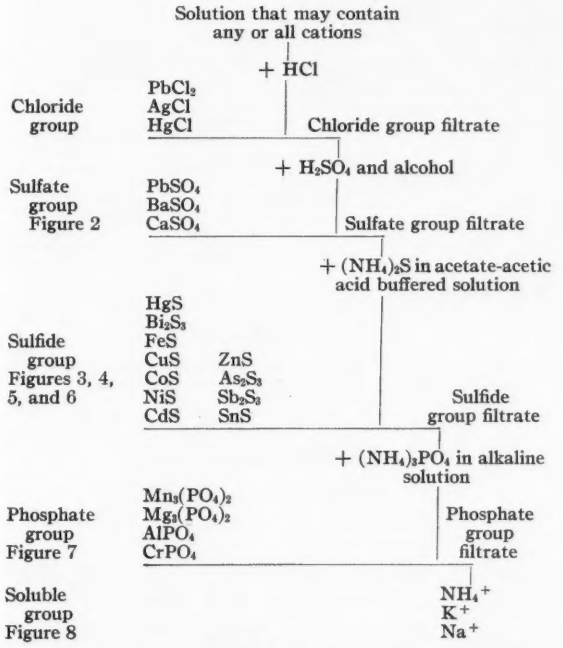

FIGURE 1.—THE CATIONS ARE SEPARATED INTO GROUPS

systems appear to have possibilities. When placed in neutral or alkaline solutions that are later properly acidified, sodium thiosulfate will cleanly and completely precipitate mercury, bismuth, copper, arsenic, antimony, and tin as sulfides. In student hands we found that the act of acidification required a higher degree of manipulative skill than we were able to impart. We also found that acidification of sodium thiosulfate often resulted in the formation of sulfur in excessive quantity. Inexperienced students often mistook these sulfur residues for bona fide precipitates and lost much time in trying to analyze them. Alkali sulfides in alkaline solution will precipitate a considerable number of cations completely and cleanly, but the precipitates of cobalt and nickel formed in this way are notorious because of the way in which they pass through filters. The cobalt-nickel difficulty may be helped by using an alkali sulfide to form a precipitate in an alkaline solution which is later acidified, or the alkali sulfide may be added directly to a previously acidified solution, but such manipulations lead to indeterminate results because the number of different metallic sulfide precipitates finally obtained will vary with the final acidity of the solution, which is apt to be irregular in value. A similar difficulty is often met in adjusting the acidity of the solution in which the Fresenius system hydrogen sulfide group is precipitated. The use of alkali sulfides in acid solutions also leads to the formation of quantities of free sulfur which is undesirable. We seemed to have reached an impasse till we had the thought of trying to use an alkali sulfide in an acetate-acetic acid buffered solution. This thought proved to be a fortunate one and its use is the chief point of difference between the Iowa System and other non-hydrogen sulfide systems. We describe only the last and current one of the five sulfide ion-using systems that we have tried with our classes. This is done in the next section.

THE IOWA SYSTEM OF QUALITATIVE ANALYSIS

A small book would be needed to describe the Iowa System in working detail. Our classes use a mimeographed book for this purpose. The present description is conveyed largely by means of graphic outlines. For the help of readers unfamiliar with the use of such outlines, we may state that vertical lines indicate operations, adding of reagents, boiling, and so forth, while horizontal lines imply the separation of precipitates by filtration. The composition of the precipitates and the treatment to which the precipitates are later subjected are indicated at the left ends of the

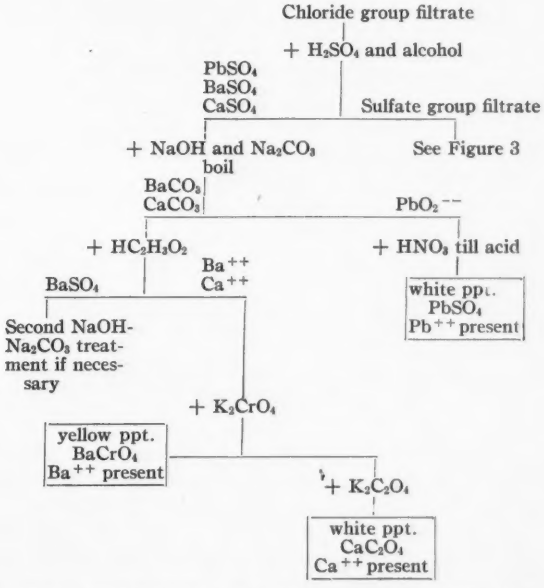

FIGURE 2.—THE PRECIPITATION AND ANALYSIS OF THE SULFATE GROUP

horizontal lines, while the filtrates and their later treatment are indicated at the right ends of the horizontal lines. A short vertical line pointing upward at the end of a horizontal line indicates that the substance indicated adjacent to the short vertical line was discarded. The general idea of these graphic outlines is similar to the idea underlying flow sheets used to indicate industrial processes. The cations included in the Iowa System are the same as those usually included in the Fresenius System, with the exception of strontium, which is omitted for reasons which will be mentioned later.

After the chloride group has been separated, it is analyzed by use of currently conventional methods, which present no novel aspects and which are omitted at this point.

Observation: The sodium hydroxide-sodium carbonate mixture is more effective than sodium carbonate solution alone for transposing barium sulfate to barium carbonate. Small quantities of barium sulfate are transposed completely by a single treatment. Larger quantities are eighty per cent. transposed by one treatment and completely transposed by two treatments.

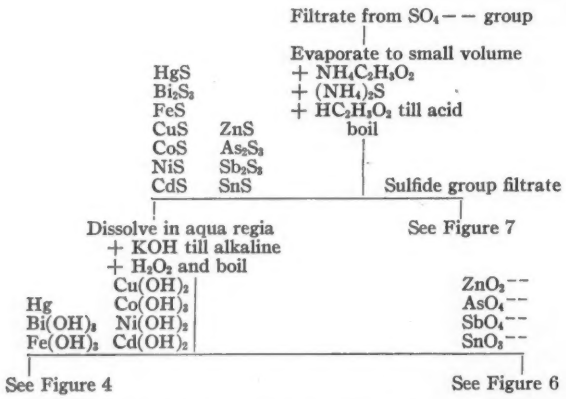

FIGURE 3.—PRECIPITATION OF THE SULFIDE GROUP AND SEPARATION OF THE SULFIDE GROUP INTO THE IRON AND TIN GROUPS

Observations: (1) The evaporation of the alcohol-containing filtrate from the Sulfate Group eliminates alcohol and incidentally reduces any chromate or permanganate that may be present. Since the precipitation of pentavalent arsenic as sulfide presents no difficulty, we presume that it is also reduced, though we have never experimentally verified this opinion.

(2) Cobalt and nickel form easily filterable precipitates when precipitated as sulfides in acetate-acetic acid buffered solutions.

(3) Potassium hydroxide rather than sodium hydroxide is used to separate the iron from the tin group because, at times, antimony hydroxide or sodium antimonate is incompletely dissolved by excess sodium hydroxide. However, sodium hydroxide may be used as the quantity of undissolved antimony precipitate is small.

(4) Hydrogen peroxide serves a number of useful purposes. The oxidation of the oxidizable Tin Group ions renders their ions more soluble. Mercury, in the absence of cobalt, is reduced to the metallic form and the hydroxides of copper and cobalt are rendered much

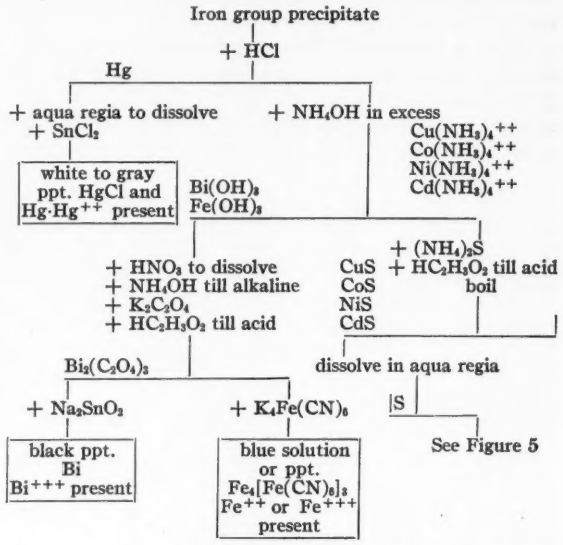

FIGURE 4.—IRON GROUP ANALYSIS. SEPARATION AND IDENTIFICATION OF MERCURY, BISMUTH, AND IRON

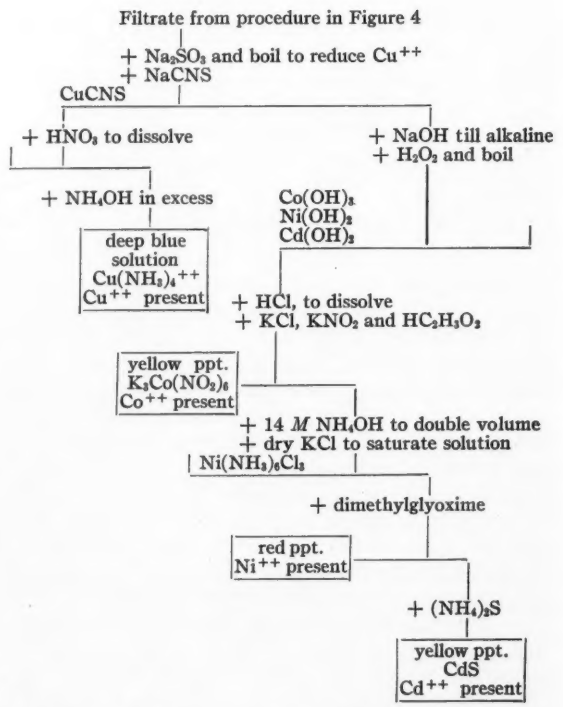

FIGURE 5.—IRON GROUP ANALYSIS. SEPARATION AND IDENTIFICATION OF COPPER, COBALT, NICKEL, AND CADMIUM

less soluble. However, traces of copper fall in the tin group, but the quantity is negligible.

Observation: The above-indicated mercury treatment is satisfactory in the hands of an experienced analyst, so long as cobalt is absent. The presence of cobalt appears to interfere with or prevent the reduction of mercury to the metallic state by hydrogen peroxide. Freshmen using this scheme fail to detect mercury about half the time. We believe that frequently this failure is due to the fact that the metallic mercury precipitated is so inconspicuous in color and small in bulk as to escape notice.

Observation: So far as we know, the precipitation of nickel in strongly ammoniacal solution with potassium chloride is new. This procedure removes all but small quantities of nickel, leaving just enough to react nicely with dimethylglyoxime.

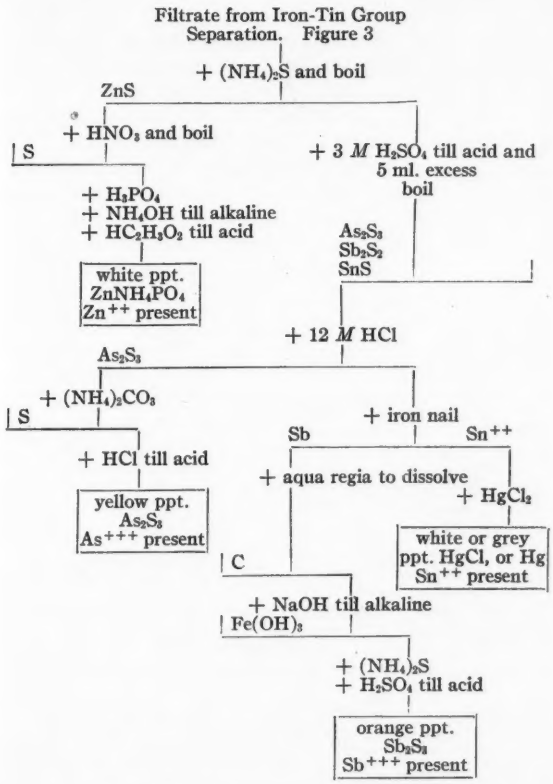

FIGURE 6.—ANALYSIS OF THE TIN GROUP

Comment: The procedure indicated in Figure 8 uses a portion of the original sample. This is unavoidable in the case of ammonium and less laborious in the cases of potassium and sodium. However, the filtrate from the Phosphate Group may be used for the detection of potassium and sodium, but first phosphate and acetate ions must be removed. Phosphate may be removed by acidifying the Phosphate Group filtrate with acetic acid, precipitating phosphate ion with

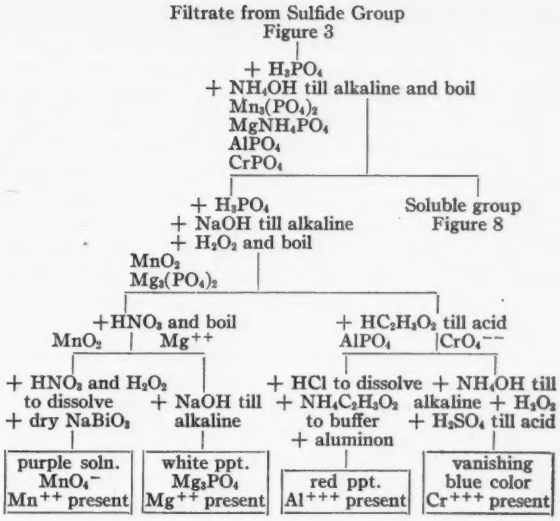

FIGURE 7.—PRECIPITATION AND ANALYSIS OF THE PHOSPHATE GROUP

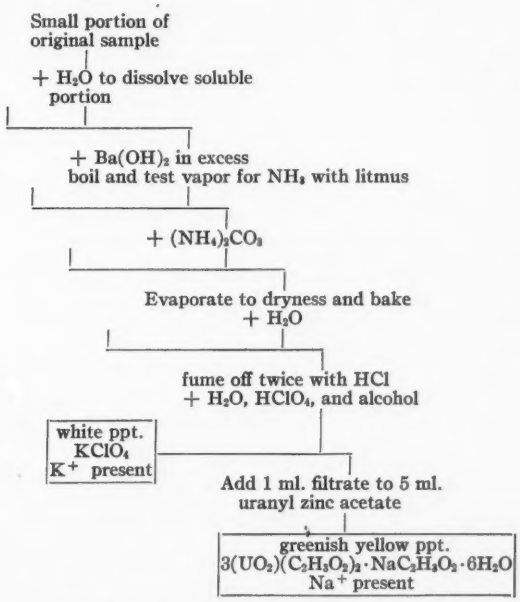
Small portion of original sample
+ H_2O to dissolve soluble portion
+ $Ba(OH)_2$ in excess boil and test vapor for NH_3 with litmus
+ $(NH_4)_2CO_3$
Evaporate to dryness and bake
+ H_2O
fume off twice with HCl
+ H_2O, $HClO_4$, and alcohol
white ppt. $KClO_4$ K^+ present
Add 1 ml. filtrate to 5 ml. uranyl zinc acetate
greenish yellow ppt. $3(UO_2)(C_2H_3O_2)_2 \cdot NaC_2H_3O_2 \cdot 6H_2O$ Na^+ present

FIGURE 8.—ANALYSIS OF THE SOLUBLE GROUP

ferric chloride and filtering out ferric phosphate. Ammonium acetate cannot be removed by sublimation but may be removed by fuming off with strong nitric acid. After the removal of phosphate and acetate ion, the directions implied in Figure 8 may be used for the detection of potassium and sodium. Use of a separate portion of the original sample is less laborious.

GENERAL COMMENTS

We believe that the chief purposes of offering a course in qualitative analysis to freshmen is to famil-

iarize students with the properties and reactions of inorganic substances and that the detection of cations, *per se*, is of secondary value. We believe that flame tests, bead tests, and tests using intricate organic compounds have little instructional value. Whenever possible, their use has been discarded. In the matter of strontium, we know of no strontium procedure useful for freshmen that does not finish with two white precipitates that depend upon flame tests for their identification. Hence we have omitted strontium. However, strontium might be included in the present sulfate group with slight additional manipulation.

With the exceptions of dimethylglyoxime, aluminon, and uranyl zinc acetate, the Iowa System employs no reagents that are uncommon or expensive. The required quantities of the three unusual reagents used are so small that their cost is nominal.

The Iowa System in no case uses different portions of the same solution for the detection of different cations, but each cation is individually isolated.

The presence of phosphates in the original sample causes no serious dislocation of the System, only a transposition of some of the manipulations indicated in the figures. Manganese falls with bismuth and iron, chromium and aluminum fall with the Tin Group, while magnesium falls in the filtrate from the Sulfide Group. These modifications are included in the mimeographed book but are omitted here for the sake of simplicity.

Students detect zinc and magnesium more frequently with the Iowa System than with the Fresenius System. Cobalt and nickel are handled more expeditiously. The chief weakness of the Iowa System in its current form is the frequent failure to detect mercury when present. We plan to attempt to correct this and other faults that further use may indicate to be desirable. We are also toying with the idea of putting the Iowa System on a semimicro basis. We have eliminated hydrogen sulfide, and the air in our laboratories is reasonably pure so long as not more than twenty-five or thirty students are working at once, but with large sections the air still contains an undesirably large quantity of fumes.

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A formula following a reference indicates one of the principal reagents used in the scheme of that particular author.

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(*Continued from page 401*)

firm or invalidate my personal ideas." .... "I derive the greatest pleasure from this work; when I think I am advancing, when by torturing my mind I surmount a difficulty, to feel here is a real truth; this may seem absurd to you, but I have the conviction of having done my duty." He called Science his fifth child.

Fifty years of labor brought no general acceptance of his views. "Does that mean that I am wrong? I do not altogether think so." As early as 1858 he had believed energy and mass interconvertible, many had declared his soda process impracticable. Even though he stood alone, he felt "to change would be to destroy himself."

Five years were required to perfect the application of a single chemical reaction, how long would be necessary to solve the multitudinous, complex problems of the physical and social worlds? His failure lay mostly in the magnitude of his task, but his confidence that the human mind can penetrate the secrets of nature and human behavior and find truth, his desire to use this truth for the benefit of mankind, this was his success. Ernest Solvay died at Brussels on May 26, 1922.

(*Contributed by Ralph E. Oesper and Clara Deasy, University of Cincinnati*)

ORGANIC REAGENTS *in the* QUALITATIVE ANALYSIS COURSE*

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IF ONE looks back over the course of development in the science of qualitative analysis and in the methods of teaching it, he can discern three more or less distinctly different periods. The first of these occupies roughly the latter part of the nineteenth century and is characterized by the initiation, gradual improvement, and widespread adoption of the familiar hydrogen sulfide system of cation analysis. A dominant figure in this period was that of C. Remigius Fresenius, whose book, "Anleitung zur qualitativen chemischen Analyse," was first published in 1841. The many editions of this work had an influence on practically every other book of the period, and it was accepted everywhere as a standard reference.

The second stage in the development of our science and pedagogy of qualitative analysis has resulted from the incorporation into the course of the ionic theory and its corollaries. Whereas in the previous period the emphasis had been on analytical procedure, early in the present century the textbooks began to appropriate the Arrhenius theory and with it to build up a theoretical portion of the course which has now grown to such proportions as to almost overshadow that part which was originally of such paramount importance that the course was called qualitative *analysis*. It is necessary now that the student in the course of this title spend a great deal of his time in studying the theories of ionization, of precipitation, of atomic structure, of the nature of valence forces—all of them necessary for a foundation of the study of chemistry but not all of them inherently essential for the study and practice of qualitative analysis.

Within the last few years, however, interest has revived in the analytical portion of the course and it seems nearly certain that this interest will be maintained long enough and will reach such proportions as to be considered a third stage in the evolution of the course. Evidence of this increased interest in practical analytical methods is abundant. At least two textbook manuals have appeared in recent years in which the traditional hydrogen sulfide separations have been replaced by non-hydrogen sulfide schemes. Semimicro methods are receiving attention in textbooks and in journal articles. Organic reagents are finding more extensive usage than in previous years and more of them are being discovered to have value in detection methods. Symposia on various phases of analysis at recent meetings of the American Chemical Society, the formation in the Society of a new division of Microchemistry, the enlargement of the *Analytical Edition* of *Industrial and Engineering Chemistry* all point to the increased interest of our profession in problems of chemical analysis.

In keeping with these recent developments, the teacher who desires to make some modifications in the method of presenting the laboratory portion of his course in qualitative analysis has these three lines from which to choose: (1) non-hydrogen sulfide schemes, with group separations made on the basis of reactions with other ions; (2) semimicro procedures which may follow the usual group separation schemes or may be based on a large number of specific tests and different separations; and (3) the introduction of a large number of organic reagents as confirmatory tests and as tests to be made on the original solution. In the last case the analytical scheme as a whole may be little changed.

It is the purpose of the present paper to indicate some of the advantages as well as the disadvantages in the use of organic compounds as reagents in the elementary qualitative analysis course.

While the advantages of the sensitivity and specificity of organic reagents are obvious in practical analysis, the wisdom of their unrestricted introduction into the elementary course is frequently questioned. Generally, the compounds used as reagents are of such complexity that the immature student cannot be expected to know the formulas nor how to use them with comprehension in equations. This being the case, it is argued that the student should not be given these complex reagents, for in their use he learns no chemistry. While this and other arguments may be more or less successfully refuted by the proponents of organic reagents, it appears to the author that the basic question is one dependent on the aims of the course and that it is of more profit that these be considered as the source of the answer to the question of organic reagents in the course.

There is general agreement among teachers as to some of the things which should make up the course in qualitative analysis. There can be no absolute agreement on all points because of the diversity of types of schools in which it is given and because of varying times allotted to it in the curricula. In general, however, it

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is expected that the student in the course achieve a degree of familiarity with the following topics:

(1) The metals in their elemental and ionic forms, their classifications, and the general properties of the various groups in the various classifications; their relationship to the non-metals on the basis of the periodic table.

(2) An extension in the applications of the ionic theory and the law of mass action.

(3) Elementary conceptions of atomic structure and the physical basis of valence.

(4) Oxidation-reduction equations.

(5) The technic and methods of detecting the common cations and anions in more or less complex mixtures.

The laboratory work of the course should be an aid in the presentation of topics 1, 2, and possibly 4, in addition to 5. The amount of time to be allowed for the matters which are not strictly qualitative analysis varies with conditions and schools, but no matter how much emphasis be placed on them we will inevitably come finally to the fifth item which is certainly a part of the aim of every teacher of qualitative analysis—to study "the technic and methods of detecting the common cations and anions in more or less complex mixtures."

There is unquestionably a certain amount of value in the usual analytical schemes for the illustration of the properties of the ions, the application of the law of mass action, and other principles, but it is the opinion of the writer that it is neither necessary nor justifiable to consider that the analytical work has this as its chief function. A group of experiments may be planned specifically for the illustration of each principle and general set of properties, so that the time remaining may have as its chief aim the study of methods of analysis. If this view is accepted the conclusion is almost forced upon us that we should give the student the best possible procedures to follow in the analysis of his unknowns. We place emphasis on the unknowns by grading the reports; the student certainly feels that it is important for him to report correctly on the content of his unknowns. It matters nothing to him that he may be illustrating the solubility product principle or the common ion effect or some other theory or law in the reactions carried out on his unknown. His attention is focused—as it should be—on his analysis. If there are simple means by which he can complete an analysis in three hours instead of six with no decrease in accuracy, he should be taught to use the shorter method. There is no practical or pedagogical merit in unnecessary tedium.

Semimicro methods eliminate much time loss by using small volumes of solutions and by using the centrifuge for making separations of precipitates from the solution. Increased usage of more nearly specific reagents still further aids in this direction by avoiding entirely some of the previously necessary precipitations and filtrations. Although it has not yet been realized in practice, it is entirely possible that within the next ten years a scheme will have been developed of specific tests for each of the ions so that no separations will be necessary. When that time comes will we feel that the student should be forced to make his analyses by separations into groups which are in turn broken up into smaller groups so that a detection reaction can be carried out without interference? If we do have reagents which may be used without separation into groups might it not become common practice for analyses to be made in this way and in order to impress on the student the similarities and dissimilarities of the elements to develop an elementary course in inorganic preparations in which some of the metals and some of the common salts are prepared from naturally occurring raw materials? There is no inherent sanctity in a six or seven group-separation analytical procedure if such separations are unnecessary for successful detection of the ions of the mixture; if the aim were to isolate a particular element or compound, the necessity of making separations would be obvious.

The plan which the author has followed for introducing the students to the advantages in the use of organic reagents and in tests on small amounts of unknown has been in using a number of unusual tests which may be satisfactorily performed on the original unknown solution. This plan has the practical advantage that the tests are applicable to any system of analysis without the difficulty of fitting them into the procedure at a proper place. It emphasizes in the student's mind the specific nature of some of the reagents and thus gives him some idea of practical methods for the detection of the ions. The spot and drop tests illustrate the convenience with which small volumes of solution may be qualitatively analyzed. The rapidity of the tests makes possible their inclusion with the regular procedure. A student may run through the tests for the twelve ions, Bi, Sn (ous), Sn (ic), Fe (ous), Fe (ic), Al, Cr, Mn, Ni, Co, Zn, and Ba, in an hour. Errors are infrequent, especially with Bi and Zn, both of which are frequently missed on the regular procedures.

Even though they are not specific enough to be used on the "original" solution, many organic reagents have already been widely adopted in the qualitative analysis schemes for use in confirmatory tests. Dimethylglyoxime for nickel is standard procedure and has been for thirty years. "Aluminon" is widely used for the confirmation of aluminum. Diphenylcarbazide is used for chromium after oxidation to chromate, nitroso R salt is prescribed in many manuals for cobalt, and the blue lake of *p*-nitrobenzene-azo-resorcinol with magnesium hydroxide has been found to have advantages over the use of the phosphate precipitation alone. In all of these the distinctive property of the organic reagents in giving characteristic colors gives them an advantage over the inorganic reagents. Student and instructor alike appreciate them because of the definiteness with which they indicate the absence or presence of the ion for which the tests are made.

It is not necessary that the student be left entirely

ignorant of the composition of the organic reagents and of their mode of reaction. In many cases, symbolic simplifications can be made to represent the formulas and it can be pointed out that the reactions are of the same type as illustrated with the simpler compounds: salt formation or oxidation and reduction. If the complete structural formulas be omitted, there need be little beyond the comprehension of the first-year student.

To briefly summarize the content and intent of this paper, it may be stated that it has been pointed out that there appears to be a marked revival of interest among teachers in the analytical portion of the course in qualitative analysis, that it is highly desirable that the student be given analytical methods which lead to correct results in a minimum of time, and that organic reagents because of their sensitivity, specificity, and definiteness of reaction have already contributed, and will contribute more, to the improvement of the analytical procedures.

The CHEMIST *at* WORK

ROY I. GRADY AND JOHN W. CHITTUM

XXIII. RESEARCH IN A SOILS LABORATORY

ROBERT L. STARKEY

Dr. Starkey is a graduate of Massachusetts Agricultural College and of Rutgers University. He served as Instructor in Bacteriology at the University of Minnesota, 1924–1926. Since 1926 he has served as Associate Professor of Soil Microbiology in the Soils Department of Rutgers University and as Associate Microbiologist at the New Jersey Agricultural Experiment Station, New Brunswick, New Jersey. At present Dr. Starkey is in Holland on a Rockefeller Foundation Fellowship for advanced study.

He is the author of articles on soil microörganisms and their activities, and co-author with Dr. S. A. Waksman of "The Soil and the Microbe."

In this article Dr. Starkey describes some of the chemical aspects of microbiological studies on soils.

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The investigator of soils deals with an extremely complicated physical system which includes particles varying in size from those more than a millimeter in diameter to particles of colloidal dimensions. These particles differ in composition and many of them are very complex substances. The colloidal particles in particular undergo rapid changes. The soil moisture which bathes the solid material is a dilute solution which also varies in composition. The nature of the solid phase becomes more involved through the occurrence of a great diversity of organic materials associated with the mineral particles. In this complex environment there occur microörganisms which bring about direct modifications of many of the organic and inorganic materials and cause further alterations through secondary changes. The soil atmosphere is also modified by microbial action. Plant roots enter this system and initiate and continue a series of alterations in the environment.

Left undisturbed and supporting the natural vegetation, soils have a tendency to retain their plant nutrients and persist in a state of potential high fertility. When broken and tilled for economic crops, the course is reversed and the fertility resulting through ages of development, gradually decreases. It is in connection

FIGURE 1.—VIEW OF SOIL MICROBIOLOGICAL LABORATORY USED FOR CHEMICAL AND BACTERIOLOGICAL WORK; STILLS AND INOCULATING CHAMBER SHOWN IN BACKGROUND

with problems of the country's soil resources that the investigator applies his ingenuity. Few practices are equally effective on all soils; even within small areas a great diversity of soils may be encountered which require different handling. The complex nature of soil itself and the great diversity of soil types in our nation defy simple analysis. It is the fascination of obtaining some insight into the general laws regulating the activities in this complex system which is one of the greatest rewards of attainment in the field of soil science.

To cope with the diverse problems which continuously confront agriculturalists, the governments of the various states and the country as a unit have developed a large body of research workers active in

FIGURE 2.—VIEW OF SOIL LABORATORY FOR GAS ANALYSIS, ETHER EXTRACTION, TITRATION, AND MISCELLANEOUS CHEMICAL STUDIES

agricultural experiment stations in each state and in Washington. Many of the studies which they pursue have to do with solving specific problems of local significance, offering promise of immediate practical value, such as the determination of means of providing the most favorable balance of nutrients in a specific soil for some crop. The use of large quantities of fertilizer materials has introduced many problems both as to the response in immediate plant growth and as to the changes which may result in the soil itself over short and extended periods of time. Many of the studies are more general in character, being concerned with the discovery of the exact nature of the soil constituents, their reactions with one another or with substances which may be introduced into the soil, as well as the influences of climate and vegetation upon the alteration of the soil constituents.

The various fields embraced by soil science may be well indicated by the sections into which the International Society of Soil Science is divided. For convenience in correlating the various studies, the organization is separated into six units. The first deals with soil physics and mechanical analysis, the second with soil chemistry, the third with soil microbiology and biochemistry, the fourth with soil fertility and plant physiology, the fifth with the origin of soils and their classification, and the sixth with reclamation, drainage, irrigation, erosion, and tillage and calls for the services of the engineer. The interests of the chemist are not confined to the second division although his major attention is attracted here to the studies of the elementary composition of soils, factors determining the reaction of soils and means of controlling them, the nature of the compounds occurring in soils, the reactions of compounds with one another and their response to physical changes and to various chemicals which may become introduced into the soil. The chemist's services are required in solving many of the problems in microbiology since the organisms living in the soil act as chemical agents; one of the principal interests in this field is to determine the chemical nature of these transformations and the factors determining the direction and extent of the reactions. Soil fertility needs the chemist to study the nature and preparation of fertilizers, the effects of such substances upon soils and the development of plants, the control of soil fertility and the determination of the causes of soil deterioration and means of amelioration. Since soil classification is based largely upon chemical characteristics and in view of the fact that soil formation involves chemical and physico-chemical changes, chemical training is indispensable in this field. The border line of physics and chemistry offers particular promise to the investigator. The recognition of the importance of the colloids in determining soil behavior calls for the best efforts of the well-trained scientist in the solution of many problems of immediate practical value and fundamental significance.

It can be realized that the chemist will find a host of problems in soil science demanding skill and ingenuity. One or two examples may suffice to indicate the nature of the approach to these problems. Some years ago the director of these laboratories conceived the idea that the farmers might profit from the preparation of available phosphates from rock phosphate on the farms. It was known that sulfur would undergo oxidation to sulfuric acid in soils and it appeared logical to mix rock phosphate, sulfur, and soil in composts and note the results. It was found that in such mixtures, there was a rapid increase in acidity and that this change was accompanied by an increase in the soluble mono- and dibasic phosphates at the expense of the insoluble phosphate rock. The characteristics of the transformation suggested that biological factors were concerned. This was particularly emphasized by the fact that inoculation of a new compost with material from an active compost increased the rate of the reaction. Microörganisms were isolated by technics commonly employed for soil organisms and many attempts were made to cultivate sulfur-oxidizing bacteria from the composts without success. Finally, by use of a highly selective acid mineral

medium, containing sulfur, it was possible to obtain growth of bacteria which had quite unusual characteristics. This organism, which was new to science, had the capacity of developing in the absence of organic foods which are required by most microörganisms; it obtained its energy for development from the oxidation of sulfur to sulfuric acid and satisfied its requirements for carbon for growth from carbon dioxide. What was more remarkable was that it failed to grow at neutrality or at alkaline reactions but developed rapidly under acid conditions and increased the acidity during growth, to concentrations stronger than are tolerated by any other known living cells. The isolation of the agent responsible for the production of the acidity in the composts opened possibilities beyond those of the originally conceived idea. It was observed that the acidity of soils could be increased by the oxidation of applied sulfur. The oxidation was considerably accelerated by inoculation of the sulfur with the sulfur bacterium since it is not commonly distributed in soils and appears to be much more active than other sulfur bacteria in soils. Although it is not commonly desirable to increase soil acidity, it has been found to be an effective means of controlling scab infection of potatoes. Furthermore, in the reclamation of alkali soils, investigations indicate that the changes following oxidation of sulfur in the soils considerably facilitates leaching to remove excess salts.

A further illustration may indicate the application of chemical approach to a microbiological problem. It has long been known that the organic matter in soils tends to become somewhat similar in nature irrespective of the nature of the organic plant residues which become incorporated as green manures, waste plant parts, or animal manures. This is particularly indicated by the fact that the ratio of carbon to nitrogen in the soil organic matter is approximately 10:1. There is little reason why the organic nitrogen should persist in soils for any appreciable period of time if it existed free as protein or its decomposition products, since they are quite readily attacked by microörganisms and would soon disappear entirely. Studies were made of the principal groups of organic materials which occur in higher plants. It was found that the relative amounts of these substances were different at various stages of growth, a greater quantity of the readily decomposable substances occurring in young plants. Incidentally, this permitted a fairly accurate estimation of the influence of plant residues upon soil conditions and plant growth if knowledge of the type of plant and stage of growth was available.

Among the plant constituents, the lignins were found most resistant to decomposition and these increased in percentage as well as total amounts with development of the herbaceous vegetation. Analyses of the soil organic matter revealed that it was composed largely of lignin-like substances associated with some nitrogenous materials. In studying the reactions between various organic plant substances, the behavior of lignin and proteins was particularly suggestive. Both lignin and proteins may be dissolved in alkaline solutions. When solutions of these two substances are mixed and acid is added, a precipitate is obtained which appears to be a chemical or physico-chemical compound of the lignin and protein. This substance resembles the material which comprises the majority of the soil organic matter. The two behave similarly to chemical reagents and physical tests. Most striking is the fact that the protein in this combination resists microbial attack although the protein is very readily decomposed in the absence of the lignin. It seems reasonable to expect that the portion of the organic matter which persists in soils represents such a protein-lignin combination and that the rate of the disappearance of the soil organic matter is controlled largely by the rate of decomposition of the lignin-like substances.

These studies have far-reaching significance. They suggest means of controlling the organic matter in the soil; they offer explanations for the extremely significant base combining properties of the soil organic matter. Basic principles underlying the preparation of artificial composts for cultivation of mushrooms depend upon knowledge of the chemical activities of microörganisms in their attack of the plant residues used as raw materials. There is likelihood that a great variety of plant wastes can supplant animal manures in mushroom cultivation, with scientific control. The nature of the processes concerned in the formation of peats and coals also appears clearer in the light of these studies on soil organic matter.

Any general examination of the field of soil science suggests a host of problems justifying the best efforts of the scientist. The complexity of the medium should attract rather than discourage the investigator since the possibility that facts of great importance still remain undisclosed can hardly be doubted. The opportunity of seeing practical application of the results of your efforts is a further incentive to accomplishment.

[Dr. Starkey's statement of qualifications and training required for such work is given below.]

Above all, the investigator in soils should have a genuine interest in agriculture, the farmer, and his problems. He should have a liking for plant growth and a curiosity about natural phenomena.

A thorough training in the fundamental sciences is necessary and this should include botany, zoölogy, and bacteriology, with emphasis upon the physiological and biochemical characteristics of the organisms. A sound training in qualitative, quantitative, physical, and organic chemistry is particularly desirable. The principles of geology with emphasis upon structural geology should be obtained. It should be apparent that information in soils and the characteristics of economic plants should be required. A reading knowledge of French and German is also indispensable. Many of these subjects may be postponed until the period of graduate study.

The position of research worker is an enviable one, but it entails certain obligations which must be accepted by the initiate. He should not expect rapid advance-

ment nor sudden financial independence. The qualities of character which are expected in a soil chemist differ little from those which serve one well in most serious fields of effort. Not only must he be honest, versatile, original, and ambitious, but he must be patient and willing to forego the satisfaction of quick results and sudden success for the attainments of rather extended periods of logical investigation and systematic analysis. He should be fair and willing to share the rewards of coöperative effort with those whose services have contributed in the attainment. To these qualities should be added that of industry, inspired by spontaneous enthusiasm in the work at hand. Still appropriate is the frequently repeated phrase—industry is the best substitute for genius.

XXIV. THE PETROLEUM CHEMIST

CARY R. WAGNER

The writer of this article is well qualified to discuss the work of the petroleum chemist. Mr. Wagner has been actively engaged in this work for twenty years. Since 1924 he has been connected with the Pure Oil Company—for six years as Assistant Chief Chemist and the remaining time as Chief Chemist. He has done extended research work in vapor phase cracking and in polymerization.

He was graduated from the College of Wooster in 1915. His graduate study was done at Purdue University.

Mr. Wagner has been secretary of the Petroleum Division of the American Chemical Society continuously since 1929 except for the two years, 1930–1932, when he was Chairman of the Division. He is a member of a number of scientific and learned societies.

In addition to his duties with the Pure Oil Company, he is President and Director of the Gasoline Antioxidant Company, and Director of the Gyro Process Company.

It is believed that the large number of illustrations sent by Mr. Wagner will help the reader to understand the duties of the petroleum chemist.

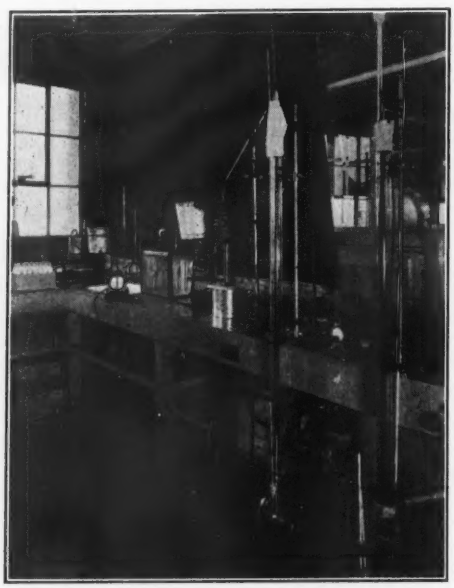

FIGURE 1.—CRUDE ASSAY COLUMN

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The past history of the petroleum chemist does not cover a large span of years. Three decades ago, when kerosene was the main product from petroleum and gasoline was being poured on creeks and streams to float away or burn, the petroleum chemist was practically unknown. With the advent of the automobile and the necessity for gasoline, oils, and greases, the field became ripe for men with technical knowledge. One need only to glance at the problems that are constantly occurring in the field to realize what a petroleum chemist does.

Let us suppose, as is constantly occurring, that a discovery well in a new field is completely successful and large quantities of a new type crude become available. Immediately a sample is rushed to the laboratory for examination. In the laboratory all the physical characteristics of the crude are first determined—gravity, flash point, viscosity, solidification temperature, and so forth.

Then the crude is charged to a distillation unit where by the use of fire, vacuum, and steam, the petroleum chemist closely fractionates the material. The small cuts are then blended to determine the possible yields of various products. Full tests on these blends will indicate the yield and quality of gasoline, kerosene, gas oil, light and heavy lubricating oils, fuel oil, or whatever other products are desired. From such an analysis cost accountants can determine the preferable products to refine from the crude in actual practice.

Perhaps it is also desired to know the quantity of

cracked gasoline that can be made by charging any portion of this crude oil to cracking stills. Another petroleum chemist is operating a miniature oil cracking unit from which can be obtained approximate yields of gasoline as well as tests on the gasoline.

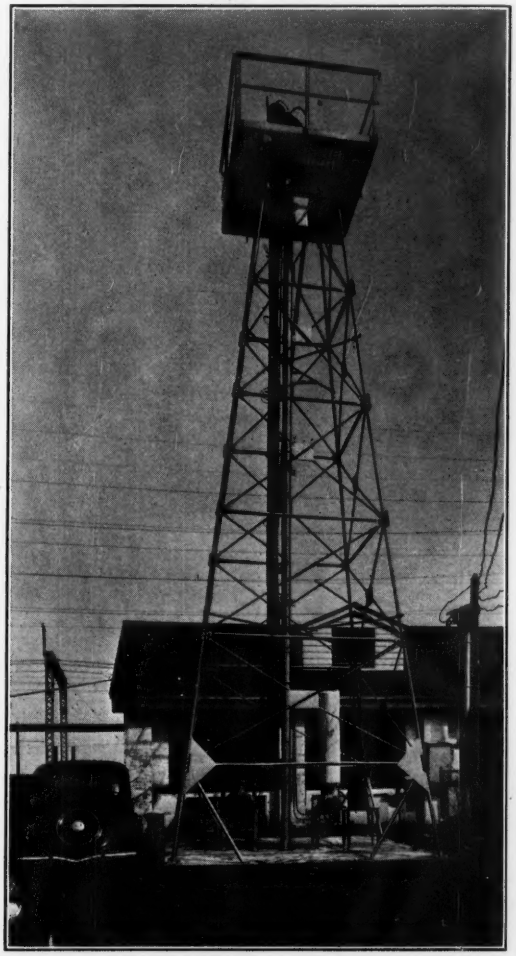


FIGURE 2.—TWO-INCH EXPERIMENTAL COLUMN

To return to the original crude as it comes from the well, probably a large amount of gaseous material is shipped to the laboratory, and the petroleum chemist, by low-temperature fractionation, determines its constituents. Especially it is desired to know the amount of recoverable gasoline held in it as gas.

The design of complete refineries may be based upon the results the petroleum chemist obtains in the analysis of such crude oil.

Let us note some problems that are immediately passed on to the petroleum chemist when they occur in the refineries. Perhaps our new crude, whose refining has been determined by laboratory analysis, is giving excellent yields and the results are as forecast. But trouble develops. The refinery reports that still tubes are becoming crusted with a hard cake that interferes with heat transfer. Samples of the crust are furnished the laboratory for analysis, as well as samples of the crude being used at the time. The petroleum chemist finds there are now very small amounts of salt water in

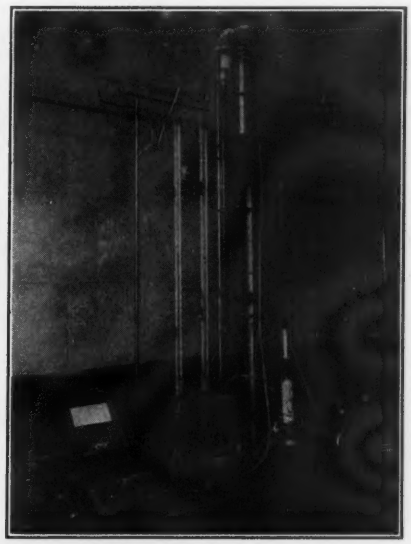


FIGURE 3.—GAS ANALYSIS. PODBIELNIAK APPARATUS

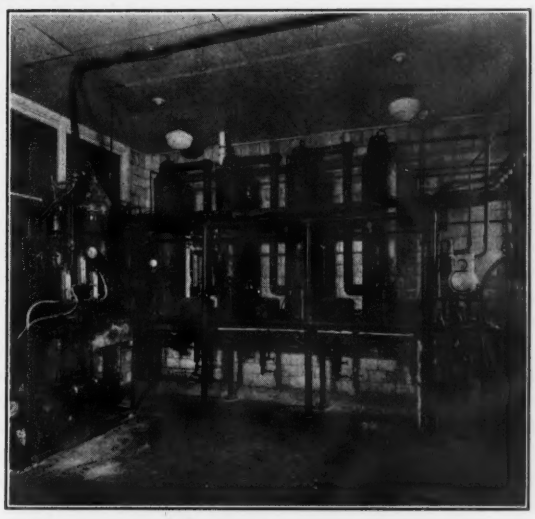


FIGURE 4.—EXPERIMENTAL TUBE STILL AND FRACTIONATING TOWER

the crude oil and its evaporation is causing salt deposition in the tubes. He must immediately determine the most economical method of freeing the crude oil of this impurity. Perhaps heated settling tanks will be sufficient, perhaps chemical treatment will be necessary, but, whatever is required, it is up to the petroleum chemist to furnish definite information and instructions to the refinery as quickly as possible.

And now arises another major problem. This crude is being supplied in large quantities and excellent lubricating oils are being derived from it. The petroleum chemist is asked, "Can greases of satisfactory quality be made from these oils, and what changes in our present formulas will be necessary?" Thus he embarks upon another program of investigation.

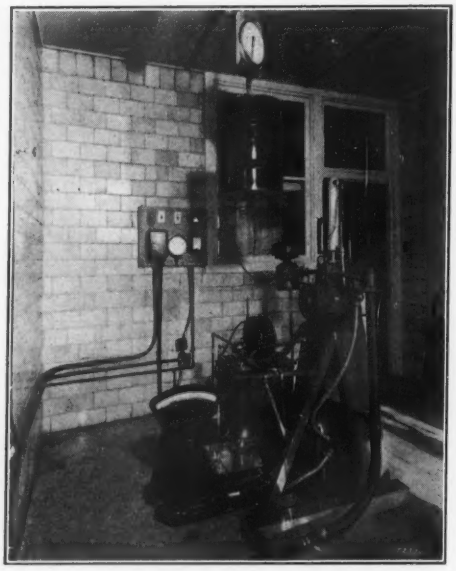


FIGURE 5.—ENGINE USED IN DETERMINING: GUM DEPOSIT AND POWER OUTPUT OF MOTOR FUEL

Although our hypothetical new crude has offered a rapid survey of various types of work done by the petroleum chemist, of course, new crudes are not a daily occurrence. However, each of the problems herein discussed is typical of those constantly confronting the technical men.

The advances of automotive engineering are constantly bringing new problems. The automobile of today requires far different lubrication than that of several years ago, and the petroleum chemist must constantly keep abreast of engineering development.

Extreme pressure lubricants are a recent product made necessary by new type gears. Ordinary lubricant films would break down under conditions which this type lubricant meets. A real advance in automotive engineering would have been impossible if the petroleum chemist had not developed a new type of lubricant to fill its needs. The fractional, almost microscopic clearances throughout every part of the modern automobile are becoming smaller each year. The petroleum chemist must keep pace by developing lubricants that afford adequate lubrication under such conditions.

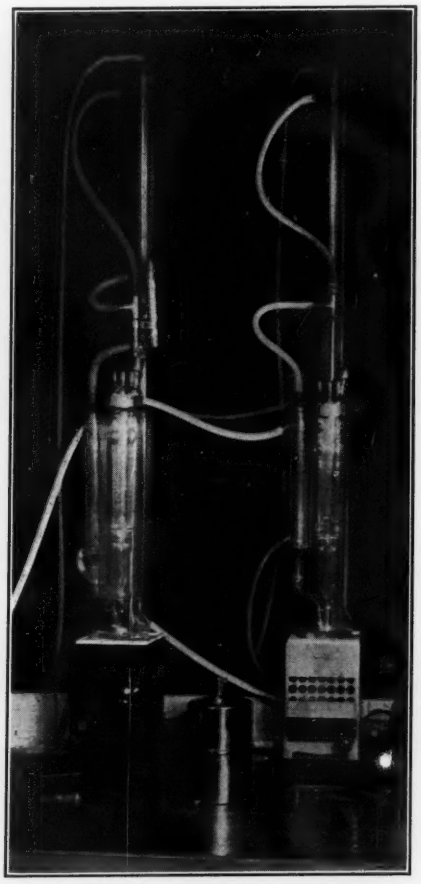


FIGURE 6.—FITZ SIMONS VISCOSIMETER

Solvent refining is one of the latest developments that the petroleum chemist has brought to the aid of the refiner. Through such processes the non-lubricating portion of viscous oils can be washed out and the unadulterated lubricating portions made available for use.

Recently the petroleum chemist has also made available to the refiner pour depressants. These materials, added in small quantity to the lubricating oils, cause the oil to remain fluid at low temperatures, thus affording adequate winter lubrication.

Not in lubrication alone has the petroleum chemist been of assistance to the automotive engineer. Year

after year, higher compression motors are being manufactured and sold, and the petroleum chemist must keep pace with satisfactory fuels. A necessary adjunct to every petroleum chemical laboratory is an automotive laboratory where the petroleum chemist and automotive engineer work hand in hand on fuel and lubrication problems.

Large petroleum companies today have expanded to produce so many related products that the petroleum chemist has one of the most varied fields. A list of some products outside the fuel and lubrication field will give an insight into some of the additional problems of the petroleum chemist.

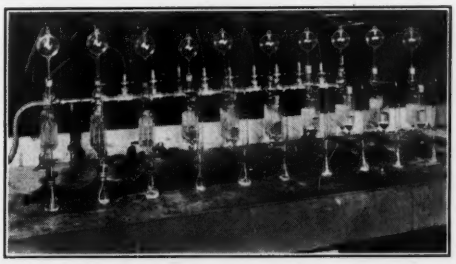


FIGURE 7.—LAMP SULFUR APPARATUS—SET FOR MULTIPLE OPERATION

1. Solvents.
   Paint, varnish, and lacquer solvents.
   Rubber solvent.
   Cleaning naphtha.
   From the manufacture of paint solvents some petroleum companies have gone a step further and now manufacture paints and varnishes.
2. Specialties.
   Floor and auto cleaners and polishes.
   Soaps and shampoos.
   Candles.
   Medicinal products.
   Waterproofing materials.
   Binders.
   Resins.
   Insect sprays.
   Naphthenic acid.
3. Synthetic materials.
   Cracking still gases, high in unsaturates, are now being used to manufacture many of the synthetic solvents.
   Complex alcohols that five years ago were laboratory curiosities are now commonplace in the trade, and many are made synthetically from petroleum gases.
   Polymerization of unsaturates has also led to the manufacture of synthetic resins.

All these products are the result of the work of the petroleum chemist and engineer. Through their efforts the list will be constantly increasing.

Like all related industries, the refining of petroleum requires chemists to perform the routine work that is necessary to keep established plants running successfully. Constant checks on raw materials, refining agents, and finished products require the attention of hundreds of petroleum chemists in every large organization. These men are the backbone of the industry, guardians of the company's integrity, as proved by the quality of the product it sells.

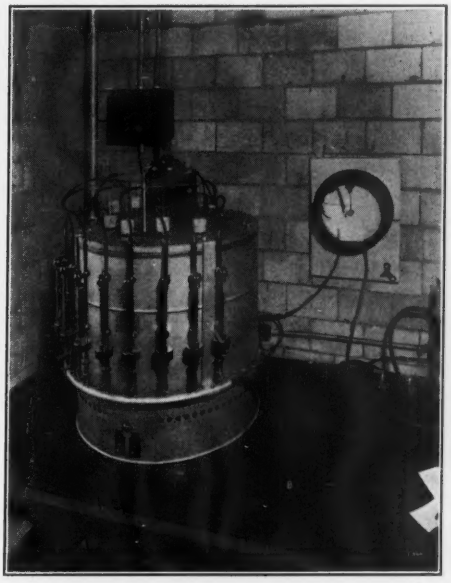


FIGURE 8.—INDIANA OXIDATION TESTING APPARATUS

XIV. THE CHEMIST AT WORK. MY WORK WITH CHEMICAL ABSTRACTS—A CORRECTION

As the result of an error, the statement in the second sentence of this article is incorrect. The correct version is as follows: "Yet with approximately sixty-five thousand abstracts appearing in a year, some twenty-five full-time workers with extra helpers at rush periods find more than enough to keep them busy in the main office."

The DEVELOPMENT *of* PROTEIN CHEMISTRY*

EDUARD FÄRBER

Newark, New Jersey

AN ATTEMPT to describe the historical development of a science may adopt one of three different methods. The first method is the historical narrative in which the deeds of different scientists are recounted according to their importance and originality. The second method is the description of the gradual development of ideas from their earliest inception to the present time. The third method combines, as it were, the other two, in that it not only describes the gradual evolution of a science to its present status by recounting achievements in consecutive periods of time, but attempts to forecast further progress in view of past history and present status. I have chosen the last method.

To choose definite periods in an article of this kind is rather difficult. One cannot select certain dates or years because first attempts and practical results or proofs are often many years apart. To make a division according to methods would result in the same difficulties, as it has often taken long investigations to prove the value of a method. I have, therefore, somewhat arbitrarily divided the "modern" development into three periods: (1) up to the time of Liebig, (2) from Liebig to Emil Fischer, and (3) Emil Fischer to the present.

How recent protein chemistry is as a science becomes evident when one considers that the nitrogen content of what was then known as albumin, was not discovered until 1786. This discovery is of such importance that one can consider the date as the beginning of a new period. Whatever came before this time was only a preparation. One examined the anatomically different parts of the body and its excretions, one determined color, odor, taste, but upon heating one ininvariably found the general "elements." This is the time which shall be discussed in the first part of this article.

1. Time of preparation to 1786.—After a beginning had been made in this manner to determine the substances that might be present in organisms and different parts of the body, a large number of analytical examinations was made. These were accomplished with the aid of the new elementary theory and the discovery of methods of quantitative combustion analysis. The influence of simple chemicals on albumin was also determined. This period of time, in which the first analytical and chemical experiments with proteins were made, extends approximately from Berthollet to Liebig.

2. From 1786 to the middle of the nineteenth century.—Actually the year 1840 should be considered the end of this period, although naturally, only with respect to certain phases of the subject. From this time on specialized theoretical studies predominate. More delicate analytical methods have been evolved, and the specific action of enzymes produces much material for further investigation.

3. From the middle to the end of the nineteenth century.—At this point synthesis takes its place alongside of analysis. Neither the thought nor the aim is new, only the specificity of the questions and the realization of the difficulty of obtaining answers. The next part, therefore, begins with the work of Emil Fischer.

4. The bases of development since 1890.—Many volumes could be written about this period, if the attempt were made to give even an approximately complete description. F. Lieben, in his "History of Physiological Chemistry" (Leipzig and Wien, **1935**), gives a more complete story of protein chemistry than is undertaken here. The history of the different amino acids is completely covered in *Chemical Reviews*.[1]

PREPARATIVE TIME TO 1786

Of albumin, as present in eggs and milk, it was known that the material was coagulated by heat and was precipitated from milk by rennet. This had been described by Dioscorides in A.D. 80. Naturally the old artisans—the tanners and glue-makers—knew much more about the behavior of albuminous substances, about their decomposition and conservation, their capability of swelling and hardening. Science had little knowledge of these things. The knowledge of metals and stones was of much more importance for centuries to come.

Medical men looked upon body fluids as homogeneous systems. The disputes between the different medical schools, for instance, revolved about the question as to whether or not the body fluids or the "pneumata" were responsible for illness and health. Paracelsus, who opposed the humoral pathology, advanced the following argument: "In disease one notices solid excretions—gallstones, and gravel in the

* Presented before the Division of the History of Chemistry at the ninety-fourth meeting of the A. C. S., Rochester, N. Y., September 6, 1937.

[1] VICKERY, H. B. AND C. L. A. SCHMIDT, *Chem. Reviews*, 9 169–318 (1931.)

urine. These diseases are stone and sand and clay. Now, tell me, could they become stone, or gravel, or sand, or clay, or glue if they were not always present as such? Could a sand, or clay, or glue form within a human body if it had not been there since birth?"[2]

Fermentation and decomposition of organic substances were technically used many centuries ago, and many questions were asked as to the "essence" of these phenomena. George Ernst Stahl, the author of a book on fermentation ("*Zymotechnia fundamentalisive fermentationis. . . .*," Halle, **1697**) based his differentiation between the living and the non-living world upon the theory that putrefaction takes place only in lifeless parts of the body.

His contemporary, Kunckel, also deals with fermentation. Fermentation is caused by beer yeast. But he is only interested in whether yeast is a sour or sweet or bitter principle. As it had never been observed that sour things become sweet, but rather, always that sweet things become sour, therefore yeast could not be sour. There is a little bitterness in yeast, but it is not entirely bitter, for otherwise bitter things should produce fermentation. Hops alone should, then, be sufficient for fermentation, but even hops require the aid of yeast. Furthermore, he concludes that the bile, being a bitter thing, is essential to fermentation in the intestines. "The stomach of a human is like something in which digestion is started with a little heat. This digestion immediately starts fermentation and the viscosum is separated; one part is made into blood, the other into milk." Later, during his travels in Saxony, he found out where yeast came from. He wondered why the bakers in Torgu got their yeast from each other and by adding it to the dough kept up an unending supply of yeast. The bakers of Hertzberg used to get their yeast from Torgu, because they did not bake as frequently, and their ferment spoiled. After much questioning, he finally found an old man, the last keeper of the secret, who had the recipe for producing yeast, "which is nothing but some boiled hops, wheat flour, the white of an egg, and a little sugar." From this, the old man told him, the baker could produce a ferment which would last forever. "Now, behold, does this ferment, which must have been discovered by a very smart man, not consist of a viscous bitterness?—which acts in the terra viscosa of the flour. At first the mucilage of the egg helps; but the sugar also helps, which is a temperament, out of which a secret little acid is formed in the first substance. And this is the rarest which I could find in my life of the origin of yeast. You can draw your conclusions from this, where all misery of the human body finds its origin, no matter which part of the body is afflicted. There are different fermentations, produced by a slight warmth, and they form out of its own viscose the cause in the same manner as some beers putrefy before they ferment."

This is an example of what a famous chemist at the beginning of the eighteenth century thought of the origin of yeast, and its effects. It would be tedious to quote all the different opinions regarding the compositions of organisms and the parts of the human body containing albumin which were rampant at that time. The conceptions which predominated at that time and up to the end of the time period of the division, will be clearly shown by the following summary.

Starting with substances of rather violent action, we can take phosphorus. As phosphoric acid could be obtained from many animal sources, the universal opinion was that it was *the* animal acid. Scheele found this acid also in bone ashes. Other animal acids are those obtained by the distillation of butter, ants, and fats, which can be differentiated from the mineral acid by their oil content—the same as the vegetable acids.

Berliner-blau (Berlin blue), produced by the color chemist Diesbach, with a salt of tartar (potassium carbonate) which was used in 1710 by Dippel in the distillation of animal oils. The process of its manufacture was at first kept a secret, but in 1724 Woodward published an article describing its preparation from blood. It took years to find out that blood, as such, was not necessary for its manufacture, especially after Macquer in 1752 extracted the coloring matter of Berlin blue with alkali. In doing so he acquired a method "to discover all kinds of metallic salts in mineral substances and anywhere else." Accordingly, Berlin blue is "nothing but iron, which becomes blue by absorbing some matter, which can be added or extracted by alkali according to circumstances."

What kind of matter it is, cannot be stated at the time. In the distillation of Berlin blue an oil is obtained similar to animal oil. Can one deduce therefrom that in the preparation of the dye some oil remained in the alkali, or does even the purest animal charcoal contain oil?

Blood can be dried on the water bath, according to Boerhaave. Further heating produces a volatile alkali and an animal oil, at first watery, later more viscous. The remaining ash contains iron, and, according to Scheele, calcium phosphate. The coagulation of blood convinced Scopoli that blood is not entirely animal, but retains some relationship to milk. The separation of the blood serum from the red precipitate was described by Boerhaave. The iron which was found in the blood ashes was looked upon as the cause of its red color, "it is not the dye itself, but it binds this coloring matter and determines its actions."

Rouelle wrote about the salts in the blood in 1773 and 1776, and he was able to demonstrate the presence of free mineral alkali, as was Proust.

This and a few observations regarding the expression of water from the blood clot and the comification of the fibrous part of the blood, was all that was known of the chemical characteristics of blood in 1780.

Eggs contain an oil in the yolk. The similarity to the oil content of vegetable seed is noted. Eggs are used as varnish in dyeing. In 1728 Beccaria found a sticky substance in flour, especially wheat flour, which acted like a vegetable-animal substance. Incineration

[2] *Op. Paramirum*, III, 1.

or distillation produced substances similar to the animal ones. It is similar to the cheesy part of the milk. Whether there is any nourishment in it, cannot be said, but that it is of importance in baking has been shown by the extensive researches of Parmentier.

Gastric juice is described; its behavior in distillation and drying, and also the taste, is noted. Human gastric juice is "middle salty," in herbivore "alkaline," in birds "sour." Spallanzi showed the "mighty forces" exerted by the gastric juice upon food even outside the stomach. Bile produces a volatile alkali upon heating, the residue is an animal earth. On account of its purifying powers it is of a soapy nature and contains, like soap, an oil and a volatile and a fixed alkali. Sebastian Goldwitz contradicts this statement in his "Neue Versuche zu einer wahren Physiologie der Galle" (New experiments for a true physiology of bile), Bamberg, **1785.** Its components are "except a coagulable lymph, a peculiar moisture, consisting of lymph, combustibles, and a little earth." Its cleaning powers are not a sign of a soapy nature, according to Lonhardi, but due to a relationship to wool and silk, which is greater than that of the fatty impurities.

"It seems that the bodies of all animals are composed mostly of a jelly-like substance," says Berthollet. He wanted to explore the nature of animal and vegetable matter by decomposing them with nitric acid. Whether gelatin (glue) or silk is treated with nitric acid, the main product is a saccharic acid or a salt which seems similar. More important than the results of such chemical reactions at that time was the analysis by heat. Distillation easily showed the relationship of all animal matter—odor, oils, and maybe the presence of a volatile alkali in the distillate. "Even the horn of animals gives the same components in the distillation as all other animal matter," says Macquer.

Horn and blood were used for the preparation of potassium ferrocyanide. Chemical analyses of this compound soon led toward a knowledge of the proteins.

The vegetable kingdom also had its proteins: *i. e.*, for the chemist of that period, materials which coagulated with heat and which showed in distillation the typical animal products. The conception of the animal principle at that was almost equivalent to the conception of an element. We observed how Kunckel in his explanation of the origin and effect of yeast used the terms "the bitter" and "the sweet" as more or less equivalent to elements. Even oxygen was at first looked upon as a "principle" and came only later, although comparatively soon, to be acknowledged as an element in the present sense.

This conception reappears in an article on proteins published about 1838. The rather mystical explanation and description of the character of ferments and similar substances, while no longer accepted by the science of chemistry, is taken as a fact in philosophy, especially natural philosophy, up to the beginning of the nineteenth century. If one takes into consideration that the majority of academically educated chemists of the period attended schools of that kind, it can easily be understood why at that time practical work with an apothecary was much more helpful to the chemist than university training.

Up to the year 1786 we hardly find a chemical distinction between the various proteins and very few methods for protein examination. It was a process of slow evolution which finally brought about the knowledge that these substances were not only components of animal matter but, like inorganic substances, suitable objects of investigation. Great enthusiasm was aroused by the discovery that the various substances reacted similarly in distillation, which was at that time considered a most extraordinary phenomenon: substances of such great difference in appearance and organic significance as horn and blood plasma, gluten and bile showed the same principle.

FROM 1786 TO ABOUT 1840

The result of the distillation of Berlin blue was explained by Scheele upon the assumption that the dyestuff was composed of oil and ammonia. He was able to produce potassium ferrocyanide from potassium and carbon only after the addition of ammonium. According to this theory hydrocyanic acid also contained ammonium. Berthollet described its behavior as analogous to that of hydrosulfuric acid (H_2S), and considered it free from oxygen, but composed of the elements, nitrogen, hydrogen, and carbon.

The presence of nitrogen in hydrocyanic acid and therefore in potassium ferrocyanide, does not presuppose that it was formed from the ammonia in the blood or bone. It was even shown that if meat was heated with dilute nitric acid, nitrogen was formed (Berthollet, 1786). Blood, according to Haller is "comme de la chair coulante." That albumin was common in the animal kingdom was shown by the coagulability of milk and blood and by the presence of coagulable substances in other body fluids. That albumin is also to be found quite frequently in the vegetable kingdom is emphasized by Fourcroy (about 1800) and he is quite proud of the fact that he was the first to have recognized albumin as one of the components of plants.

Incineration analysis of organic substances is now being developed, and Berzelius presents the results in form of relative atomic weights. Proteins were not included in these first experiments—not until after 1830. As we want to determine how constituents of the human body became objects of chemical investigations we must also consider the development of the conception of vegetable and animal substances. Berzelius, and later on Liebig, contributed, mostly by their systematic work. Berzelius divided these vital substances in two parts, their "dead substratium" and the "vital essence." The first is the substance, which we analyze and identify by its proportionate atomic content, the second is the inexplicable by which this material is formed and was made different from the pure inorganic substances. The conceptions as to the

character and significance of this mysterious vital force changed. Liebig still considered this force in its full meaning at a time when Berzelius wrote in 1839: "It is obvious, that a single universal vital force is not sufficient as an explanation. We must not only assume a special one for each living being, but also that this force would follow the products of the living tissue after these have been separated from the living body in which they originated. But in chemical operations, like dry distillation, for instance, they undergo changes, and new substances come into existence, without the influence of the organs of the living body, which are only subject to the natural inorganic forces. All that is left for us to do, is to ascertain the peculiar circumstances in organic processes under which the universal forces of nature show their effectiveness. But the same forces presuppose the same laws of Nature. This indicates that the laws applicable to combinations of elements of inorganic nature must also apply to those of organic nature."

Theoretically, the conception of a common principle was more and more abandoned. One knew of no methods by which it could be proved, and the later-developed methods did not show any sign of its existence.

These methods were adopted from other fields of chemistry for the protein chemistry. Various solvents or salt formations were used to split up mixtures and isolate substances. Fourcroy describes the brain as "cette énigme anatomique et physiologique, qu'aucun physicien n'a encore pu deviner, représente une espèce de bouillie épaisse, de pulpe plus ou moins solide—." He treats a watery extract of brain substance with alcohol and obtains a crystalline substance. The non-homogeneity in hardness of the brain substance makes him divide this so very important and vital organ simply into softer and harder parts, but its mysterious meaning is emphasized. The partition of mixtures by crystallization from solvents led Chevreul later on (1811–23) to the discovery of the components of many fats and to the processes of saponification. Proust discovered in a similar manner two components in cheese: the oxide and that which he called "cheese acid," which was partly identical with the substance Braconnot obtained a year later from muscle fiber, and called leucine. Braconnot used stronger solvents than water and alcohol; he boiled with acids and alkalies. In this manner he obtained a few of the more simple proteins. As far as their chemical composition is concerned he is entirely in the dark. Sulfuric acid yields sugar in reacting upon wood or cotton. From gelatin he obtains also a crystallizing, sweetish substance by sulfuric acid; therefore this is gelatin sugar. Almost two decades later it was found that nitrogen was an essential component of these so-called sugars, and the name glycocol or glycine was used for a long time.

The production of asparagine was very simple. Vauquelin and Robiquet left the asparagus juice stand for some time, and separated the slowly appearing crystals. Because of its easy crystallization a substance "principe cristallisable" must be present, similar to that found in the inorganic salts. In 1833 Pelouze found nitrogen in asparagine, and, even after hydrolysis with barium hydroxide, a nitrogenous acid—aspartic acid—was obtained.

From a special kind of urinary calculi Wollaston obtained cystic oxide (1810), which was analyzed by Prout in 1820, and its exact nitrogen content determined. But only in 1837 was the sulfur content demonstrated by Baudrimont and Malaguti.

The foregoing are the most essential steps in the chemistry of proteins for this period. The systematic division of the entire field is still according to anatomy. Berzelius divides animal chemistry in his textbook into the following principal groups: (1) nervous, (2) vascular system, (3) blood-forming organs (digestion), (4) excretions, (5) sensory organs, (6) organs of locomotion, (7) sexual organs, (8) peculiar animal substances, (9) products of decomposition. Leucine is naturally placed in the last group.

The chemical methods used at that time explain why the chemistry of carbon combinations was so slow in development and that especially protein chemistry is of so recent years. The number of protein components, belonging to the last group of Berzelius, was larger in 1840 than those which were obtained by weaker-acting reagents. We noted asparagine as an example of the vegetable proteins, and can take creatine as an example of the animal proteins. Chevreul who was a master in crystallizing substances, obtained crystallized creatine (0.03 per cent.) from meat extract, which he treated with alcohol. With these experiments the separation of components present in only small amounts started.

Boiling with water was one of the methods Berzelius used as a means for the decomposition of animal matter. It was used to a large extent to obtain glue from skin, and so forth. Thenard treated solutions of glue with chlorine gas and described a peculiar resulting combination. Braconnot used concentrated sulfuric acid to separate some of the components. He obtained glycine and leucine. With nitric acid, glue yielded malic and oxalic acids. It seemed almost as if these chemical reactions confirmed the results of distillation in their monotony. Invariably the same reaction products were obtained, whether skin, meat, or casein was used. But close inspection showed decided differences in some instances. In Dippel's oil are four different "oil-like salt bases," according to Unverdorben. He names them as follows: odorin, after its odor; animin, to signify its animal source; olanin, a combined form of oleum animale. The different pyrrole and anilin oils were called amolin by Unverdorben. The influence of nitric acid did not produce only the above-named products. Fourcroy and Vauquelin observed a yellow acid as an intermediate product. Mulder later called this acid xanthoproteic acid. From cholesterol Pelletier and Caventou obtained by oxidation with nitric acid their "acide cholesterique." Prout discovered purpuric acid, which is formed from uric acid, when dissolved in nitric acid and after saturation with ammonia is per-

mitted to evaporate. Vauquelin obtained another by a different treatment of uric acid with nitric acid. Fourcroy in his great work (1801) describes blood in a manner, which, while still rather mystical, can be looked upon as a physico-chemical description. Undoubtedly that was his intention, but the influence of mysticism was still strong. The blood is divided into serum, fibrin, and protein. Sodium, phosphorus, and iron are present.

Entirely different and much more thorough are the facts published by Berzelius thirty years later. The fibrin has been treated with acids and alkalies, its fat extracted by ether and alcohol. The blood coloring matter has been chemically studied, and the iron has received special attention. Heinrich Rose, for instance, says that such substances as sugar or glue prevent the precipitation of iron by the addition of alkalies, and that this is also the case with the products obtained by the action of chlorine on the blood coloring matter. Berzelius reaches this conclusion, based upon all these analyses that: "The principal components of blood are therefore fibrin, coloring matter, and protein, but which react so similarly to chemical reagents, that the assumption seems justified, that they are three conditions or modifications of the same animal substance brought about by as yet unknown circumstances, as for instance the coloring matter owes its characteristics to the iron content. Undoubtedly at some future time analyses made with purer substances will decide the question."

Braconnot mixed meat and concentrated sulfuric acid, separated the fat, added water, and boiled for several hours. After neutralization, filtration, and evaporation he treated with alcohol. A white, crystalline, water-soluble substance was obtained. On account of its white color he called it leucine. Berzelius writes as follows about flesh:

"Real analyses of the flesh of different animals have not yet been made. I have analyzed ordinary beef, and Braconnot an ox heart, therefore flesh of the same animal, but belonging to two different muscle systems. The results of these analyses agree entirely and I am certain that Braconnot did not know of my analysis although performed fifteen years earlier. In one hundred parts of flesh were contained:

	BERZELIUS	BRACONNOT
Meat fibers, vessels and nerves, 15.8		
	17.70	18.18
Cellular tissue, dissolved into glue by boiling, 1.9		
Soluble albumin and coloring matter	2.20	2.70
Alcoholic extract containing salts	1.80	1.94
Water extract containing salts	1.05	0.15
Sodium phosphate containing albumin	0.08	—
Water (loss)	77.17	77.03
	100.00	100.00

Braconnot says he found only potassium salts."

All the different discoveries of that period need not be described here, but only methods and means which show the historical development. In this respect the period from 1786 to about 1840 can be described as the time in which chemical analysis was constantly gaining over the old phenomenological description. In the introduction to the chapter on animal chemistry in his textbook Berzelius says:

"The living solid substances, as seen in our experiments, are in a very peculiar condition, very common in organic nature, especially in the animal kingdom, *i. e.*, the condition of *softening*, which is not to be found in inorganic nature. Chevreul has made many experiments regarding this peculiar condition of softening, which show that pure water only can accomplish it. Water containing much salt can be absorbed by dry substances only to a certain limit. But they do not undergo that softening and therefore do not attain their original appearance."

Although albumin was defined by its coagulability, it was still further characterized by its origin. Vegetable albumin remained vegetable, animal albumin, animal. But, according to Prout, the differences between the albumins can be defined by their different coagulation temperatures, which have no longer any connection to plants or animals. One splits up natural substances by solvents, primarily water and alcohol. One changes them by the addition of sulfuric or nitric acid. Then one analyzes to determine the approximate quantities of the different elements in these substances. Fourcroy compares in his great work "System" the "chimie animale vivante" with the "chemie animale morte." While in the laboratory destruction is preponderant, and the analysis always equals the extreme or maximum, nature prefers in the living substance slight changes at a time; in fact in nature we have, as it were, the minimum. One of the greatest problems of chemical science is to lessen the difference between man's and nature's methods, *i. e.*, to try to approach the more refined methods of nature.

FROM ABOUT 1840 to 1890

The year with which we shall begin this part of our survey is that in which Liebig wrote Berzelius that he "was filled with disgust and aversion to the practices going on in chemistry at this time." "Is it justified," he says, "that we try to bring about substitutions with chlorine instead of studying organic nature and its changes?" At that time he still took Mulder, who specialized in animal and vegetable chemistry, as an example. Liebig, like all geniuses, was years ahead of his time. He saw the possibilities to increase the number of chemical combinations, especially with the aid of substitutions, *ad infinitum*. To him it seemed much more important to explore the chemical processes involved in the laws of nature. Organic chemistry more and more deserted the original intent of its researches. Kekulé says in the preface of his "Textbook" (1859): "We define organic chemistry as the chemistry of carbon combinations. We do not observe thereby a contrast between organic and inorganic combinations." A year later Berthelot in his "Chémie organique fondie sur la synthèse" (1860) says: "The aim of our researches is to exclude the vital from all explanations dealing with organic chemistry." The practical problem of producing artificial dyes, and the theoretical principles laid down in Kekulé's benzene theory are two of the best known incentives for the development of the chemistry of carbon combinations.

This development naturally influenced albumin research. Very early we come upon the theme of en-

zymes, and the combination of chemical research with physiological methods.

It was the custom of the older chemistry, reaching as far back as Aristotle, to associate observed characteristics of a body with the presence of characteristic substances. This manner of thinking is still present in Mulder's protein hypothesis.

Albuminous substances, which distinguish themselves by coagulability and nitrogen content, have a common radical, protein. This protein combines with different amounts of sulfur, phosphorus, and hydrogen. This hypothesis had to be discarded, the same as many others of similar character, in view of more modern chemical analyses. Liebig, especially, demonstrated its fallacy, and it was abandoned in 1847. But the problem of discovering "nearer" components in the albuminous substances remained. While the elementary analysis of egg albumin showed certain percentages of carbon, hydrogen, nitrogen, sulfur, and oxygen, there was nothing to indicate the manner in which these elements were combined. Lieberkühn compounded the following formula, based upon the analytical figures of Dumas and Cahours: $C_{72}H_{112}N_{18}SO_{22}$. Mulder was terrified by such formulas, although in his own book on physiological chemistry (1844–51) he uses similar formulas for bile, blood, or skin.

There is one more bold hypothesis for the synthesis of albuminous substances. Sterry-Hunt insisted that they were nitriles of cellulose according to the following scheme: albuminoids = cellulose + ammonia − water. A simple proof was to heat cellulose with ammonia; albumin was to be formed by the resulting dehydration. Several investigators, among them P. Thenard and Schützenberger, believed they had accomplished this, although they were not very critical about proof. On the other hand, several crystallizing substances, which were formed by chemical reactions, were known. We have noted cystine, leucine, glycine, and asparagine. In 1846 Liebig obtained a similar product by melting raw casein in a caustic potash solution—tyrosine, which his pupil, Bopp, three years later obtained by hydrolysis with concentrated sulfuric acid. Its correct chemical constitution was determined by L. Barth twenty years later. Strecker in 1850 produced alanine from ammonium aldehyde and prussic acid and determined that it belonged to the glycocol-leucine series. Ritthausen called a nitrogenous acid, which he isolated in 1866 by boiling gluten with sulfuric acid, glutamic acid. Several albuminous substances, obtained by heating biological materials with water, acids, or alkalies were examined. Oxidation yielded mostly indistinct reaction products, which did not give much information. But hydration and hydrolysis had been successfully used in other fields of the chemistry of organisms. They yielded soaps from fats and oils, which cleared up the chemical composition of fats and oils; cellulose and starch could be converted into sugar, and could be chemically defined. After long and thorough preliminary work Schützenberger tried to use the hydrolytic splitting of albumins to determine their chemical compositions. The method he used was to heat the material with barium hydroxide in an autoclave. The volatile substances obtained were caught in hydrochloric acid. The insoluble residue was separated by filtration, and, after precipitation of the barium as barium carbonate, the reaction products were determined by distillation or evaporation. Mostly there is a decided preponderance of insoluble residue. Such a reaction could be expressed by the following formulas:

$$C_{240}H_{387}N_{66}O_{75}S_3 + 60H_2O \rightarrow 16NH_3 + 4C_2H_2O_4 + 3CO_2 + 4C_2H_4O_2 + C_{221}H_{338}N_{49}O_{105} + S_3$$

This, therefore, was more of a method to determine comparatively what amounts of ammonia and acids could be separated, for the fixed residue yielded after repeated crystallizations mostly leucine and leuceine. To determine the real components of albumin, which could be called the actual parts of the great molecule albumin, it was necessary to obtain fine cleavage products in larger amounts. Erlenmeyer and Schaeffer found the following reaction products after boiling with about forty per cent. sulfuric acid:

100 PARTS OF	PARTS LEUCINE	PARTS TYROSINE
Elastine	35–45	0.25
Fibrine	14	0.8
Egg albumin	10	1.0
Horny tissue	10	3.6

Hlalasivrtz and Habermann add stannous chloride to the hydrolizing hydrochloric acid to prevent oxidation during the three days of boiling. From casein, albumin, or legumen they then obtain considerable amounts of the chlorides of glutamic acid, ammonium, leucine, aspartic acid, and tyrosin.

But even with this method the different albuminous substances yield about the same products. Schützenberger obtains about the same products from albumin that he gets from gelatin, but still he makes up different formulas for the combination of the two substances. The concentrated alkalies act differently at fusing temperature, than the diluted acids or alkalies. Aside from acetic, butyric, and valeric acids and phenol, the volatile products, pyrrole, indole, skatole, are formed. But the cleavage of albuminous substances by hydrolysis, tried for decades with some modifications on a great variety of material, does not lead to a complete qualitative or quantitative analysis. It is natural that other means were tried to change the albuminous substance chemically into known or easily recognizable products. Oxidation with nitric acid did not seem suitable, and bromine, which yielded rather large amounts of bromoform and mono-organic acids, as well as leucine, was tried.

All these methods were taken from inorganic chemistry. There was an entirely different method, and to a certain extent a more natural one, to analyze albumin. It had been known since the time of Spallanzani, that the gastric juice affected foods even outside the body. It was also discovered that hydrochloric acid helped to attain the results at normal temperature. In 1836

Theodor Schwann described the dissolution of albuminous substances by an extract from the gastric glands. These extracts, therefore, contained a ferment; he called it pepsin. He purified it by precipitation with lead acetate. He found that it loses its effect upon boiling, or upon the addition of some chemicals.

Soon other extracts from body organs that dissolved coagulated albumin were found. Therapeutically such preparations were in use as early as 1852. Naturally, the various products offered for sale were at first quite different in action and value. Only after purification methods had been devised could a purer product be expected. A mass of problems was here ready for research. Where did such ferments in animals or plants occur, and how could their actions be ascertained and used? It was probably of importance that the first of these ferments discovered, ampesin, was immediately considered equal in effect to an acid. The earlier investigators of plant and animal extracts considered it of importance to determine the taste and reaction. There had been lengthy discussions of whether or not gastric juice was acid, and why. Now it became known that the addition of acids or alkalies affected the action of the ferments. While one was almost entirely dependent upon the action of the ferments on insoluble albumin to determine their effectiveness, some very delicate methods of production were devised. Brücke, for instance, treated the mucous membrane of the stomach with five per cent. phosphoric acid, and precipitated the pepsin by neutralization with calcium phosphate. The precipitate was washed and then dissolved in hydrochloric acid. The pepsin goes into solution, and the albuminous substances remain if an alcohol-ether cholesterin solution is added. The precipitated cholesterin takes with it the pepsin, which is separated by solution in water and agitation with ether. Von Wittich used glycerine as a solvent for pepsin.

The albuminous substances which had become soluble were called peptones. That different kinds of albumin gave different peptones was determined by polarization (Henniger, 1878). After prolonged reaction pepsin also yielded the same products which were obtained by boiling with acids, among them leucine and tyrosine.

Whether the ferments were natural products or were only formed by the extraction methods was frequently discussed, especially in the case of trypsin, which Claude Bernard observed in the pancreas in 1856, and which was named by Kühne in 1867. While these ferments dissolved coagulated albumin, rennet had the opposite effect for it coagulates the casein in milk. That this was due to the action of a ferment was determined primarily by Hammersten about 1871. A present-day example gives a good illustration of the state of albumin chemistry at that time. After we had become thoroughly acquainted with the characteristics of cellulose, chemically, physically, and also technically, interest was concentrated on the other principal component of wood, lignin. It was oxidized with nitric acid, treated with chlorine and bromine, and hydrolyzed with acids and alkalies. Direct distillation was also used before treatment with chemicals. We see here a process of development very similar to that which took place decades before in albumin chemistry. Everyone who is interested in the use of lignin is waiting for that special and particular method which will eventually solve its secrets.

Albuminous substances are found in all organisms and organs. Chemically the question arises whether these products, which differ according to their sources, are actually different from each other. This depends a great deal on the methods used. It was shown that many methods yielded the same products from obviously different albuminous substances. It was clear, therefore, that the results depended upon the force of reaction. Graham in 1861 discovered a very mild method, dialysis. An animal membrane has a selective permeability for different substances. The work of Graham is not original in this respect; it was more a systematic perfection of a method which was described by Dutrochet in 1827, and for which Dubrunfaut obtained a patent in 1854 for its use to eliminate salts from molasses. He used parchment paper, which was invented a year previous, for dialyzation.

By dialysis one could first of all remove mineral salts from solutions of albumin. Such purified albumin seemed also to answer the question whether it was soluble in water only due to the small amounts of minerals and salts present, or whether it was also water soluble in a purer state. All experiments seemed to indicate that the latter was the case. The albuminous substance present in blood serum, serin, could also be obtained in a purer state by dialysis, and this method was the only method known up to 1880.

Further investigations uncovered more difficulties. Every new chemical method seems to have been developed under similar circumstances. Whenever a new way was discovered that seemed promising, it was soon seen that there was a multitude of details which had to be cleared up. In this case the questions arose as to the most suitable membrane for dialysis, the most favorable temperature, and also the optimum degree of acidity or alkalinity.

Even more complicated were the conditions due to the influence of salts on the albuminous substances. As stated before, Berzelius claimed that the dissolution of organic substances was hindered by salts. This applied only to substances with an inordinately high salt content. Albuminous substances like myosine from muscle plasma or vitamin from egg yolk were easily soluble in a ten per cent. solution of sodium chloride. Both are precipitated out of this solution by large amounts of water as well as by large amounts of salt (Kühne, 1868). Magnesium and ammonium sulfates were used as precipitants for albumin. Even these methods demanded thorough study to discover which salts, and in what concentrations, caused a change in the solubility of albumin. Again we arrive at a specialization in research. Franz Hofmeister compiled the data summarized in Table 1. The figures indicate the lower limits of concentration in moles per liter.

TABLE 1 (1888)
THE SEPARATION OF CHICKEN EGG ALBUMINOID BY ALKALI- AND MAGNESIUM-SALTS
(T = 30–40°)

	Li	*K*	*Na*	NH_4	*Mg*
Citrate	—	0.56	0.56	—	—
Tartrate	—	0.75	0.78	—	—
Sulfate	0.78	—	0.80	1.00	1.32
Acetate	—	1.67	1.69	—	—
Chloride	—	3.52	3.62	—	—
Nitrate	—	—	5.42	—	—
Chlorate	—	—	5.52	—	—

The order of tabulation seems to indicate a decrease in the effectiveness of the respective salts. Attempts were made to base a universal rule thereon, but this proved more difficult than it seemed. First of all the purity, or, more strictly speaking, the nature and quantity of impurities present, are of great importance. Specialization seems to lead to an attempt to connect certain characteristics and similarities. Thus Hofmeister believed that the salt effects applying to chicken egg albumin could be applied in the same order to the swelling of gelatine.

After mentioning these two methods of separation, let us consider which albuminous substances were known at the end of this period. Hoppe-Seyler in his textbook of 1875 gives a list of them. Of primary interest to us is the fact that now the division was no longer made according to botanical or zoölogical origin, but exclusively on the basis of material characteristics. The physiological and biological characteristics, no matter how important, can be omitted in the compilation of this list. Chemistry alone could explain quite a great deal about these substances.

TABLE OF ALBUMINOUS SUBSTANCES ACCORDING TO HOPPE-SEYLER, 1875

1. *Albumins:* soluble in water. No precipitation by dilute acids, sodium chloride, soda, platinum, hydrocyanic acid. In this group belong serin and albumin.
2. *Globulins:* insoluble in water. Soluble in weak common salt solution and in dilute acid. Coagulate with heat. Viteline, miosine, paraglobulin.
3. *Albuminates:* insoluble in water and sodium chloride solutions, easily soluble in diluted acids and soda. Not precipitated by boiling casein: and alkali albuminates.
4. *Acid-albumins* (syntonin): soluble, like *4* precipitate, on neutralization.
5. *Amyloid substance:* insoluble in water, acids, and soda solutions. Is not digested by gastric juice.
6. *Coagulable albuminoids:* solubility as in *6* but digested by gastric juice.
7. *Peptones:* soluble in water. Are not precipitated from solution by acids, alkalies, or heat.

About ten years later E. Drechsel in the "Handwörterbuch der Chemie" (1885) divides the animal albuminous substances from the vegetable. In this manner he obtains two main groups. The animal albuminous substances he subdivides into (*a*) albuminoids, which give by decomposition aromatic products (tyrosine, indole phenol, and so forth) and (*b*) glutinoids, which do not decompose into aromatic products. Under *a* the above-named albumins are mentioned. Here also their solubility is the main distinguishing guide. New products named are the proteids, *i. e.*, such albuminous substances as on analysis yield again albumins and also other substances. In this group belong, for instance, hemoglobins and mucoid substances. The other products are acids and carbohydrates.

Glutinoids are the glue-like substances easily soluble in hot water without change, and the sponge-like substances, which are either insoluble or only soluble with change.

Among the vegetable albuminous substances the following three groups are differentiated: (*1*) plant albumins, water soluble, coagulated by heat; (*2*) gluten-protein substances, insoluble in water or absolute alcohol, but soluble in dilute alcohol, coagulated by heat; (*3*) plant caseins, insoluble in water or salt solutions, soluble in dilute acids and alkalies. "Other groups corresponding to the albuminates seem to exist, but have not as yet been examined."

In each of these groups a number of substances were known but it was not always easy to ascertain whether they were identical or merely related to each other. Solubility alone did not permit a decision on this question. Several precipitation reactions with salts of heavy metals could be used at times, but they were not specific enough. Several color reactions were known: a blue and violet coloring with concentrated hydrochloric acid, after Carventou; the red reaction with mercuric nitrate, after Millon (1851), or with concentrated sulfuric acid; also a yellow reaction with concentrated nitric acid; and several similar reactions. But all substances of a group gave these reactions so that a differentiation was impossible. Elementary analysis yielded values that could be expressed by chemical formulas; but they were impossible monsters. Mulder in his "Versuch einer allgemeinen physiologischen Chemie" (1844–51) says, "The composition of the epidermis corresponds to the formula $5(C_{40}H_{66}N_{12}O_{15})lS$ but at present it is impossible to prove its correctness." The chemical formulas, which, for instance, Schützenberger composed for the albumins he studied, are in general not much more correct.

SYNTHESES

There was one more method to determine the chemistry of albuminous substances—a method, which while not initiated by Berthelot, was emphasized in his extended researches—synthesis.

"The opinion that albuminous substances are closely related to urea (that is, are complicated derivatives thereof) has gained support from the researches of Grimaux. He succeeded, by melting together uric acid and aspartic anhydride, in producing a water-soluble substance, which in many ways closely resembles albuminous substances. Especially significant is the fact that this substance coagulates, and disintegrates into carbon dioxide, ammonia and aspartic acid if heated in baryta water to 150°. But it would be premature to conclude that albuminous substances are substituted ureas." [E. Drechsel in Ladenburg's "Handwörterbuch" (1885).]

Schützenberger also tried to ascertain the constitution of albuminous substances by synthesis. He took ten grams of epichlorohydrin and four grams of urea. When heated to 135–40°, the mass became fluid, turned yellow, and yielded a product which in many respects

was similar to albuminous substances. But what chemical changes took place in the reaction is altogether obscure, and whether the product should be regarded as an albumin remains questionable.

The earlier syntheses were more important in the respect that they employed the simplest building stones of albumin. To that end one must begin with the cyanogen synthesis, which Scheele had effected in 1783 by heating together carbon, ammonium chloride, and potash, and which, forty-five years later, Desfosses achieved by leading nitrogen over a glowing mixture of caustic potash and carbon. The "artificial formation of urea," on which Wöhler made his famous report in 1828, is in reality more a rearrangement than a synthesis. From cyanogen and hydrocyanic acid the way now leads through formic acid, which Pelouze obtained in 1831 by their hydrolysis, to the first synthesis of an amino acid by Strecker in 1850. This was for him really only a detour in obtaining lactic acid from aldehyde, by which he demonstrated that the former consisted of aldehyde and formic acid. However, for his synthetic work he heated, not aldehyde, but its ammonia compound with hydrocyanic acid; thus he first obtained alanine. Then, by the action of nitric acid, the desired lactic acid was prepared.

Meat extract had become a very important material through Liebig's work. Creatine, which Chevreul (1835) had obtained by crystallization from meat extract, later offered many experimental difficulties in preparation. The problem was eventually clarified by the discovery that this substance is destroyed by the acids of meat. More thorough study showed, specifically, that creatine is easily hydrolyzed, and thereby broken down into urea and methylaminoacetic acid (sarcosine). On the other hand, one can readily split water from gelatin, and so achieve its transformation into creatinine. Now Vollhardt synthesized sarcosine by heating ethyl chloroacetate with methylamine in concentrated aqueous solution at 120–150°. Furthermore, Vollhardt converted sarcosine to creatine by uniting it with cyanamide, just as Strecker had early obtained the next lower homolog, glycocyamine, from cyanamide and glycine.

Another very important series of syntheses related to hippuric acid. This substance was isolated by Fourcroy and Vauquelin by addition of hydrochloric acid to the urine of herbivorous animals, and Liebig had shown in 1829 that it could be split into benzaldehyde, hydrocyanic acid, and formic acid. Strecker specified more exactly in 1852 that hippuric acid is an amino derivative of a glycol-benzoic acid compound. Dessaigne synthesized the acid from silver glychocolate and benzoyl chloride. The reaction may be represented as follows:

$$C_2H_3(NH_2)O_2Ag + C_7H_5OCl \rightarrow C_9H_9NO_3 + AgCl$$

It is really to be expected that the product of this reaction should have the constitution $H_2N\cdot CH_2\cdot COOC_7H_5O$, although, in reality, hippuric is obtained through a rearrangement: $C_7H_5ONH\cdot CH_2COOH$. Theodor Curtius occupied himself with this reaction at the instigation of Hermann Kolbe and found (1882) that, in addition to hippuric acid, it yielded two higher condensation products with higher amino-acid contents.

Curtius carried the work farther, though in a somewhat different direction. He removed the hydrochloric acid from the hydrochloride of ethyl aminoacetate with silver oxide and found that the ester could be distilled. It appeared to him highly important to preserve the esters, which are so sensitive to alkali in excess, and to work with highly purified materials in accurately known quantities. It developed later that it is often desirable to be less cautious in dealing with such materials. The significant simplification thereby made possible led Emil Fischer to his vast success in this field. The instability of the amino-acid esters is further evidenced by the fact that they condense spontaneously into products of higher molecular weight, in part, even upon standing in aqueous solution.

PERIOD FROM ABOUT 1890 ONWARD

In surveying the events of this period we shall examine only a few lines of inquiry that led to especially important results. To that end we shall adopt the following classification:

(1) decomposition by chemical action, and investigation of structure through synthesis;

(2) enzymatic decomposition;

(3) physicochemical investigations (X-ray patterns and molecular weights);

(4) dead and living albumin.

1. Decomposition by chemical action, and investigation of structure through synthesis.—Emil Fischer had discovered for the first time in 1884 the easily crystallizable, difficultly soluble compounds of the individual carbohydrates with phenylhydrazine. He saw how profitable it is to have a method whereby a hitherto unknown field can be opened up. He esteemed highly the work of Heinrich Kiliani (1885–86), which employed the compounds of sugars with hydrocyanic acid for the solution of structural problems. With his help it was made clear that dextrose is an aldehyde, and levulose a ketone.

He next occupied himself with the amino acids. He esterified them by the method described by Curtius, and found that they could be freed from the hydrochloric acid used in their preparation by means of concentrated alkali. Thus he could in a relatively simple manner obtain the free esters quickly and cheaply. Curtius, for one, had previously shown that the esters can be distilled *in vacuo;* Fischer found that the boiling points of the different esters lie far enough apart to permit their separation by vacuum distillation. In addition he made use of the carefully worked out methods for the precipitation of compounds (*e. g.*, by means of picric acid) to isolate these albumin building stones.

The decomposition of the building stones was based on the old methods—the action of acids or alkalies. By the investigation of casein, which extended from 1900 to 1904, his procedure may be depicted.

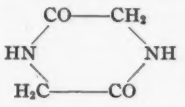
Casein is boiled with twenty-five per cent. sulfuric acid; after the removal of the hydrolyzing reagent the difficultly soluble tyrosine can be separated. It is obtained in a quantity equivalent to 4.5 per cent. of the dry starting material. In order to isolate the other cleavage products it is better to use concentrated hydrochloric acid for the decomposition. After six hours' boiling of the casein with hydrochloric acid about eleven per cent. of glutamic acid can be crystallized in the form of the hydrochloride. The concentrated filtrate is then esterified. After removal of the excess alcohol the reaction mixture was subjected to stepwise alkaline treatment. To the neutralized mixture are first added potassium carbonate solution and ether. Thereby the unstable aspartic acid is extracted from the alkaline aqueous solution immediately upon its liberation. More potassium carbonate and sodium hydroxide are then added and the extraction with ether is repeated, whereby further decomposition products are obtained. They are carefully fractionated by distillation, yielding the esters of alanine, proline, aminovaleric acid, leucine, and isoleucine in the lower-boiling fraction; the esters of aspartic and glutamic acids and of phenylalamine and serine boil higher. In the residue products of higher molecular weight (*e. g.*, leucine imide) are found. When the esters have been as completely separated from each other as possible they are converted by hydrolysis to the corresponding acids and further purified by fractional crystallization, either directly or in the form of suitable derivatives.

In this long and care-demanding way it is possible to separate and identify the degradation products much more exactly than by earlier methods. However, a considerable part of the natural material is lost by undesired side-reactions, so that at best some seventy per cent. of the starting material is recovered in the form of definite building stones.

Beside the "ester-method" evolved by Emil Fischer there gradually developed a very thoroughly investigated series of separations and characteristic reactions for the amino acids. Thereby it became possible, for example, further to characterize the basic albuminoids of cell nuclei, first brought to light by the work of Miescher in 1868 and of Kossel in 1884. The principal products of hydrolysis are three alkaline-reacting "histone bases" which are characterized as the amino acids, namely, arginine, histidine, and lysine. According to Kossel and Kutscher (1901–7) the mixture of the three acids is precipitated from the hydrolysate with phosphotungstic acid, with which they form salts. Thus separated from the other hydrolysis products, they are liberated with baryta, and then separated from each other by making use of the varying solubilities of their respective silver salts in neutral or alkaline solution. In addition, benzenesulfonyl chloride, for example, serves for the preparation of suitably separable derivatives.

According to a review published by Emil Fischer in 1916, nineteen different amino acids had been identified as products of the degradation of albuminous substances up to that time. However, the synthetic as well as the analytical methods had been decidedly improved.

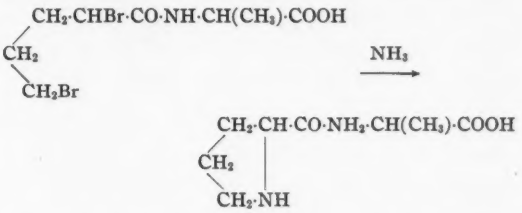
Another observation of Curtius' constituted the starting point. He found that glychocolic ester eliminates alcohol to give a dimeric product, diketopiperazine.



When this substance is boiled with concentrated hydrochloric acid the cendensation is partially reversed and glycylglycine is obtained

$$H_2N\cdot CH_2\cdot CO\cdot NH\cdot CH_2\cdot COOH$$

Especially productive was a method based upon the earlier-described syntheses. An amino acid is combined with the chloride of another acid which in turn may readily be converted into an amino acid. That is the case, for example, when an acid chloride carrying additional halogens which may later be replaced by amino groups is employed. The chloride of 1,4-dibromovaleric acid combines with alanine in alkaline solution, and through the action of ammonia the product may be converted into prolylalanine.



Chloroacetyl chloride combines in the corresponding manner with glycylglycine, obtained from diketopiperazine. If the compound is then treated with ammonia diglycylglycine is obtained.

$$ClCH_2\cdot CO\cdot Cl + H_2N\cdot CH_2\cdot CO\cdot NH\cdot CH_2\cdot COOH \xrightarrow{NH_3} H_2N\cdot CH_2\cdot CO\cdot NH\cdot CH_2\cdot CO\cdot NH\cdot CH_2\cdot COOH$$

In this manner it was possible to build ever farther, at first fundamentally—given Emil Fischer's experimental skill. In the year 1907 he described the successful preparation of a peptide containing eighteen amino acid molecules—leucyl-triglycylleucyl-triglycylleucyl-octaglycylglycine. In this manner Emil Fischer and his co-workers have prepared artificially nearly a hundred polypeptides that have the same properties as natural albuminoids. They are cloven by the same ferments and in the same manner as the albuminoids found in nature. There arises the question whether any of the naturally occurring albuminoids have been synthesized. The statistical possibilities which one can calculate from the number and nature of the building stones are so great that it seems highly improbable that one might hit upon the exact arrangement actually existent in the natural structure. As regards an artificial dyestuff such a question is of little interest, for it is much more important from the practical standpoint

to produce a substance with the desired properties than to duplicate a natural material. To the artificial construction of albuminoids from their fragments, however, this practical argument does not apply, and science must be concerned with the identity of the substances. In this sense it must be said that artificial albuminoids can be prepared, but that art does not yield those occurring in nature.

FIGURE 1

FIGURE 2

THE MONKEY MODELS OF THE BENZENE RING

These photographs were taken by Sidney Beinfest of the charcoal drawings which were made by N. A. Karoley of the pen and ink sketches which are reproduced in Gunther Bugge's "Das Buch der grossen Chemiker," Volume 2, pages 214–5, Verlag Chemie G. M. B. H., Berlin, 1930, and also in Richard Anschutz's "August Kekulé," Volume 1, pages 610–1, published by Verlag Chemie.

According to Bugge, there appeared at a banquet of the German Chemical Society a souvenir journal in which were reported the supposed proceedings of the "Durstigen Chemischen Gesellschaft" on September 20, 1886.[1]

These consisted of a series of humorous articles and poems, among which was one by C. F. Findig (according to Bugge), F. W. Finndig (according to Anschütz), "On the Constitution of Benzene." The translation follows.

"I have found that zoölogy gives the perfect means for the understanding of the behavior of carbon atoms. Just as carbon atoms possess four valences, in the same way the members of the *Quadrumana* family possess four hands with which they can grasp others and hold on to them. If one considers a group of six members of this family, for example the *Macacus Cynocephalus* forming a ring among themselves in which they alternately extend two and one hands, one obtains a most complete analogy of the Kekulé benzene hexagon (Figure 1). *Macacus Cynocephalus* possesses, in addition to his four hands, a fifth organ in the form of a caudal appendage. If one takes this into consideration, then it is possible for the six individuals of the ring shown in the illustration to combine in another manner. In this way Figure 2 is obtained.

"It seems to me most highly probable that the analogy between the *Macacus Cynocephalus* and the carbon atom is a perfect one. In this case each carbon atom in the same way possesses a caudal appendage which cannot be counted as one of the normal valences, but despite that, it is capable of grasping. As soon as this appendage, which I designate as 'caudal residual valence' comes into play, the second form of the Kekulé hexagon is produced which is obviously different from the first and must behave differently from it. According to the circumstances in which the benzene ring is found, it will take up either one or the other form, and consequently will possess an ever-changing constitution." (*Contributed by Louis Sattler of Brooklyn College.*)

[1] "Berichte der Durstigen Chemischen Gesellschaft." Unerhörter Jahrgang Nr. 20., Ausgegeben am 20., **9** (1886). Eigentum der Durstigen Chemischen Gesellschaft. Kommissionsverlag, R. Friedlander u. Sohn.

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KEEPING UP WITH CHEMISTRY

The fishermen as chemists. ANON. *Ind. Bull. of Arthur D. Little, Inc.*, **136,** 4 (May, 1938).—Chemical preservation of perishables such as fish livers for medicinal oils, waste meat for soap-making oils, fertilizers, or animal feeds are being investigated by vitamin oil-producing laboratories under fellowships of the U. S. Bureau of Fisheries whereby these oils may be better taken care of on the high seas for ultimate use. G. O.

Principles of mineral flotation. F. L. BOSQUI. *Chem. Met. Eng.*, **45,** 270–3 (May, 1938).—Flotation consists in passing a suspension of finely crushed ore in water through a series of flotation machines or "cells" where the combined effect of agitation and aëration in the presence of flotation reagents results in the separation of the floatable from the non-floatable minerals. The former collecting in the froth at the surface of the pulp are skimmed off as "concentrate" while the latter are continuously rejected as "tailings." The first essential is the production of an adequate supply of reasonably stabilized bubbles throughout the ore pulp. Frothers are added to aid this process. Frothers are heterpolar (contain both polar and non-polar groups in the molecule). They contain either a hydroxyl, carbonyl, nitrile, carboxyl, or amine group. Pine oil and cresylic acid are the best known frothers.

Microscopic examination of mineralized bubbles shows them to be lined with a single layer of mineral particles. Those which have an average size of about 2 mm. do the best work.

Collectors are also added to overcome adverse conditions on the metal surface and thus promote the attachment of the mineral to the air bubble. Those most used are the xanthates, dithiophosphates, and fatty acids.

In addition inhibitors, activators, de-activating agents, depressors, pH regulators, toxic, and antitoxic agents may also be added.

Flotation machines and costs are also described. J. W. H.

Inconsistent sugars. ANON. *Ind. Bull. of Arthur D. Little, Inc.*, **136,** 3–4 (May, 1938).—Some sugars are bitter; they may be beneficial or poisonous, reactive or inert, cheap or expensive. Sucrose or common sugar is obtained from sugar cane or beets and is relatively cheap. Crude sucrose obtained from maple trees is relatively expensive and furnishes an example of how value may depend upon the presence of an impurity, the maple flavor. Most of the dextrose is produced from the starch of corn and is perhaps the cheapest pure organic substance produced. It is a potential and an actual raw material for the production of fine chemicals. Sugars are formed in plants as carbohydrates, but sugars may also be the components of the glucosides of plants Combined with the other bitter-tasting glucosides of the plants such as prussic acid, bitter almond oil, or mustard oil they are active chemicals awaiting the time when an enzyme has a chance to set them free as when the plant cells die or the plant functions change. Sugars may "condense" to build up starch and cellulose or starch or cellulose may be inverted into sugar. There is an opportunity to use sugars as the raw materials of industry which makes use of similar material from other sources. Other sugars will be discussed in a later *Industrial Bulletin*. G. O.

Trends in processes, raw materials, and uses for sulphuric acid. T. J. KREPS. *Chem. Met. Eng.*, **45,** 22–5 (Jan., 1938).—The most important outlets for sulfuric acid in order of volume of consumption are fertilizers, petroleum refining, chemicals, by-product coke industry, cleaning of iron and steel for galvanizing, metallurgical processes, and minor uses.

Chemically this acid serves four main purposes: as a strong cheap acid; as a dehydrating agent in chemical reactions; for sulfonations; and as an oxidizing agent.

At the present time the contact process is rapidly gaining competitive success over the long-established chamber process. Whether the chamber process will be able to retain its hold on the production of 50° Bé. sulfuric acid will depend on whether its improvements will keep ahead of the new developments in the contact process.

Several kinds of raw materials may, in time, compete with those most used at present to make sulfuric acid. Among such possibilities are waste gases from sulfide smelters, sulfur in crude petroleum and coal, and ferrous sulfate waste liquors.

The elimination of the use of H_2SO_4 in making phosphate fertilizers as is now done in the electric furnace process may cut down future demand for the acid considerably. In the future sulfuric acid will also probably play a much smaller rôle in the bringing about of other chemical transformations.

In modern times sulfuric acid is only one among many chemicals. J. W. H.

Chemistry in the role of a modern Pied Piper. B. LEVITT. *Chem. Industries*, **42,** 51–2 (Jan., 1938).—Present rodent eradication depends almost wholly on chemical and biochemical research..... Trapping of rats and mice involves the necessity of final disposition, which is not only offensive, but ofttimes embarrassing. Chemical substances used for extermination are barium sulfate, thallium sulfate, arsenic trioxide, phosphorus, zinc phosphide, plaster of Paris, red squill, hydrocyanic acid gas, strychnine, sulfur, and other substances.

Certain viruses have been used as exterminators, but the United States Public Health Service does not recommend them on account of cost, uncertain action, instability, and possible creation of an immunity to their effect.

The United States Drug Administration Bulletin 238 states that thallium is among the most toxic substances recommended for rat control. Comparative tests with other rat poisons show the following minimum lethal doses:

	Mg. per kilo of body weight
Thallium	25
Arsenious oxide	20–25
Red squill powder	250
Barium carbonate	750

This article tells the method of preparation of the various poisonous mixtures in use. A. T. B.

New developments in humectants. J. R. FRORER. *Chem. Industries*, **41,** 601–3 (Dec., 1937).—Many everyday materials such as textiles, regenerated cellulose or Cellophane, tobacco, leather, and various forms of glue must be kept flexible and slightly moist to retain their usefulness. Water alone is an excellent flexibilizer. But, due to the wide range of fluctuations in atmospheric humidity, the moisture content of most substances cannot be kept at the proper value. Therefore, a humectant agent with a suitable humectant range is added to help the material retain its moisture.

"Humectant" is used to describe that class of hygroscopic materials suitable for incorporation with many materials of everyday use. They are used as agents to attract water to these materials to keep them slightly moist and flexible.

Each humectant has a different "humectant range."

By this is meant the degree of change or range in moisture content in the face of changing relative humidity conditions. Thus, a substance that takes up water readily and to a greater extent in high humidity and loses it readily and to a greater extent when subjected to low humidity is said to have a wide humectant range because its moisture content varies widely.

Conversely, a substance that takes up water slowly and to a lesser extent in high humidity and loses it slowly and to a lesser extent under conditions of low humidity is said to have a narrow or relatively stable humectant range, as it varies but little in moisture content under fluctuating moisture conditions.

The value of a material with a narrow humectant range in conditioning is very like the action of automobile springs in leveling out the bumps in the road surface. To secure maximum smoothness the reaction of the springs is controlled by a stabilizer. Similarly, an airplane is balanced by the control surfaces, but a stabilizer is used to give steadier flight in fluctuating air currents.

In the same way, a desirable humectant agent combines affinity for water with stabilizing action on the moisture content. That is, it keeps within a narrow range the moisture content fluctuations caused by wide-range humidity fluctuations.

The sugars, glycerin, and the glycols have been available for some time and their use as humectant agents is fairly well known. Sorbitol, however, as a material of industrial interest is very recent. It is found in nature in the berries of the mountain ash, in pears, cherries, and other plants, but in amounts too low to be of commercial importance. A process has recently been perfected by the Atlas Powder Company whereby sorbitol is produced synthetically on a large scale. Production is now under way at their new plant at Atlas Point, near Wilmington, Delaware.

The properties of particular interest from the point of its use as a humectant agent are (1) permanent fluidity; (2) minimum variation in hygroscopicity; (3) zero volatility; (4) high viscosity; (5) insolubility in most organic solvents; (6) stability under conditions of humectant use; (7) freedom from objectionable thermal decomposition products—such as acrolein; (8) compatibility with textiles, leather, glues, etc., and (9) freedom from objectionable taste and odor.

Sorbitol takes up less water at high relative humidities than the other poly-alcohols, and on the other hand, loses less water at low humidities than the sugars. It is this effective moisture stabilizing characteristic of sorbitol that has led to its being termed "a general purpose humectant agent."

Moreover, since sorbitol does not volatilize, as do the lower polyhydric alcohols nor dry out at low humidities as to the sugars, its stabilizing influence is retained under conditions of high temperature and humidity extremes.

In the short time that sorbitol has been available as an industrial material an unusual number of interesting applications of its moisture stabilizing power have been worked out.

A. T. B.

Forty tons of chemicals to produce one gram. A. K. KEMBAR. *Chem. Industries*, **42**, 279–80 (Mar., 1938).—"For four years a mineral refinery has operated on this continent whose uniqueness is gauged by three items of its 1938 program.

Concentrated ore to refinery	500 tons
Chemicals used in refining	2500 tons
Production of chief product	60 grams

This refinery is located at Port Hope, Ontario, near the center of Canada's most thickly populated section. Three thousand miles away, close to the Arctic Circle, on the shore of Great Bear Lake, lie the mine and mill known as Eldorado; the ore is pitchblende; the chief product is that amazingly valuable radioactive substance, radium.

In 1929, while poring over Canada's mining archives, Gilbert LeBine found a thirty-year-old reference to the beautiful effect of sunlight falling on the cobalt bloom of the sheer cliffs rising from the water's edge of an inlet of Great Bear Lake. A prospector of long experience, LeBine knew that cobalt meant silver. So he started for the far reaches of Canada's Northwest Territories. On the rim of the arctic, he found what he sought. But he found more. With the silver were extensive pitchblende deposits—and pitchblende meant radium.

"When he came out with his samples, so rich was this hand-picked ore (capable of producing one gram of radium from seven tons) that experts doubted even the word of a government official that there existed such a deposit. Despite this richness (directly responsible for a reduction of the price of radium from $70,000 to $30,000 per gram) almost insuperable difficulties had to be overcome before this richness could have commercial value. Normal winter temperature at the mine was 30° to 40° below zero. Transportation of ore and supplies twelve hundred miles to the nearest railroad was another problem. Oil wells, fortunately located a few years before and less than two hundred miles along the river, solved both problems by providing fuel for river boats, steam heat and power for the mine.

"But there was a far greater difficulty. At the time of the Eldorado discovery no one in Canada knew anything about radium extraction from pitchblende. A virtual monopoly of the radium market was held by Belgian interests producing ninety per cent. of the world's output from pitchblende deposits in the Belgian Congo. So secretive had these producers always been concerning their methods that it was clear that no help was to be had from this source. The only hope was to create a new large-scale refining process. Using the data of Madame Curie's laboratory work as a basis, experimental work was carried on until this possibility became the perfected reality now in operation at Port Hope."

A. T. B.

The dye swatch goes to town. ANON. *Chem. Industries*, **42**, 272–3 (Mar., 1938).—"A bit of cloth colored with a particular dye is the accepted method of sampling in the dyestuff trade, so accepted that it has become a habit with both dye-makers and users. Some boldly original soul among the dyestuff sellers has once in a while cut his swatches diamond shape or even in circles, but it remained for The Calco Chemical Company to break with all tradition. They cut their swatches this past season on their Azo dyes in the form of animals, put them into a circus, and brought life and human interest into the swatches."

A. T. B.

Hardwood as a chemical raw material. M. H. HAERTEL. *Chem. Industries*, **42**, 267–71 (Mar., 1938).—"The future of any industry depends on supply of raw material, continued demand for its products, and advance in manufacturing technic. On all three counts the prospects of hardwood distillation are reassuring.

"Hardwood forests are not being exhausted. Modern forest practice encourages regrowth at a rate sufficient to compensate for consumption. Only a few of the existing plants fear depletion of their wood supply. In the case of some of the enterprises nature is replacing the wood even more rapidly than it is being cut. Readjustments to type of species available and improvements in transportation methods assure a continuous supply of wood for the future.

"So far as can be foreseen there will always be a demand for methanol and acetic acid far beyond the ability of the hardwood distillation industry to supply. Difficulty on this score will not come from decreasing markets, but from the lower prices at which the synthetic product is sold. It is too early to forecast the cost of production by synthetic methods. Many engineers believe, however, that the bottom has been reached.

"The marketing of charcoal presents a real problem. In olden days almost the entire output was absorbed in the production of charcoal iron. When this market began to slip there came an insistent demand for a low-priced convenient fuel in the big cities, especially along the Atlantic Seaboard. This demand still exists. However, displacement of the old cold-water flats by apartment houses equipped with steam heat and gas stoves is a threat.

"The industry is by no means blind to this danger and is seeking new outlets. Charcoal is being reëstablished as a luxury fuel. Better-class restaurants everywhere are advertising charcoal-broiled meats. Various methods of charcoal broilers for home use are on the market. The growing tendency of Americans to spend time out in the open is cleaning up waste wood. Managements of forest and park encourage the use of charcoal, to prevent injury to plant growth and to reduce the fire hazard.

"The possibilities of adding to the list of products has by no means been exhausted. Tar, pitch, and non-condensable gases now used as plant fuel offer fields for research that are not being neglected. Wood preservatives and fine chemicals may be developed. Interesting laboratory results have been achieved, but are not sufficiently advanced to permit general discussion.

"There is an active investment of new capital in additions to hardwood distillation plants, principally in the Middle West, especially in Michigan, Tennessee and Arkansas. Chemical industry is invading the deep South. It is more than likely that the extensive hardwood areas in the Gulf States will eventually attract capital to that area.

"The old-fashioned saw-mill which uses only a part of the trees, leaving the larger part behind as a fire hazard and disease host, is on the way out. Carbonization provides an extra income, contributes to forest sanitation, and increases employment in forest areas. The products are basic to a variety of chemical process industries. Scientific knowledge is increasing and improving the output. Hardwood distillation will long be an essential part of the social and economic life of the nation."

A. T. B.

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Progress in the refining of coal during the last four years. A. SANDER. *Chem.-Ztg.*, **62**, 313–7 (May 4, 1938); *ibid.*, 333-4 (May 11, 1938).—A review. Thirty-seven references. L. S.

Possibilities of protecting materials against corrosion. W. WIEDERHOLT. *Chem.-Ztg.*, **62**, 325–8 (May 7, 1938).—A survey. L. S.

Organic precipitants in quantitative analysis. W. PRODINGER. *Chem.-Ztg.*, **62**, 373–6 (May 28, 1938).—A survey. Sixteen references. L. S.

Catalysis in polymerization reactions. R. E. VOGEL. *Chem.-Ztg.*, **62**, 51–2 (Jan. 15, 1938).—A short review. L. S.

The British chemical industry in 1937. T. W. JONES. *Chem.-Ztg.*, **62**, 85–8 (Feb. 2, 1938).—A survey. L. S.

The progress made by the beet sugar industry in 1937. W. DÖRFELDT. *Chem.-Ztg.*, **62**, 137–40 (Feb. 19, 1938).—A survey. L. S.

The oil industry of British India. F. WITTKA. *Chem.-Ztg.*, **62**, 176–7 (Mar. 19, 1938).—A survey. L. S.

The emission of radiation from chemical reactions. R. AUDUBERT. *Ang. Chem.*, **51**, 153–63 (Mar. 19, 1938).—A review covering general properties of photoelectric counting devices, results obtained from studies of physico-chemical reactions and biological phenomena, the emission of ultra-violet radiation in chemical reactions, estimation of the spectral region of the emission, emission yield (number of photons emitted), hypotheses on the emission mechanism and applications of radio chemical analyses (slow oxidation of phosphorus, anodic polarization of aluminum, thermal decomposition of azides). L. S.

Organic compounds with heavy hydrogen. F. ADICKES. *Ang. Chem.*, **51**, 89–93 (Feb. 12, 1938).—A review of the literature. Seventy-eight references. L. S.

Progress in the field of the luminescence of solids. N. RIEHL. *Ang. Chem.*, **51**, 300–4 (May 28, 1938).—A review. Twenty-seven references. L. S.

Limitations of our knowledge in the field of natural sciences. W. GERLACH. *Ang. Chem.*, **51**, 313–8 (June 4, 1938).—A survey. L. S.

New results and problems of colloidal studies. P. A. THIESSEN. *Ang. Chem.*, **51**, 318–24 (June 4, 1938).—A review. Twenty-three references. L. S.

HISTORICAL AND BIOGRAPHICAL

Sir Frederick Gowland Hopkins. H. WIELAND. *Nature*, **141**, 989–93 (June 4, 1938).—Sir Frederick Gowland Hopkins "was the first to show that carbohydrate, fat, protein and inorganic salts, even when supplied in adequate amounts, do not suffice to maintain metabolic equilibrium.....Lundin, a pupil of Gustav Bunge, was the first to show that mice could not be kept alive on a diet which had been compounded from the previously isolated constituents of milk, that is, from its carbohydrates, fats, proteins and inorganic salts. This important observation...was not followed by further research in the same direction..... In his Nobel Lecture, Hopkins acknowledges the merit of the Dutch physiologist Pekelharing in having attributed the nutritional insufficiency of the milk, thus separated into its main constituents, to the absence of unknown substances present also in other food materials; thus the vitamin concept was first clearly expressed... The most important foundation for the development of such research was laid by the well-known work of Christian Eijkman on the causation of beriberi disease (1903). It was somewhere about this time that Hopkins began his investigations of the vitamin problem..... The great advance which they brought consisted in an experimental proof of the main idea, that the deficient nutrition resulting from the administration of the necessary calories, proteins and salts in the form of a 'synthetic' diet, is caused by the absence of factors necessary for life..... Although Hopkins did not himself isolate any of the vitamins, of which he studied the effects—chiefly A and B—we are yet fully justified in regarding him as the spiritual father of vitamin chemistry. It was only by his clear physiological characterization of this group of substances that the field was prepared for the intervention of the analytical biochemist, to whom we now owe so extensive a knowledge of the vitamins hitherto isolated..."

After P. Löwi and E. Abderhalden had shown that the mixture of amino acids produced by artificial digestion of protein is just as suitable for nutrition as protein itself, Hopkins tested the nutritional importance of individual constituents by removing from the mixture one or another amino acid and administering the residue to animals. "The absence of the aliphatic amino-acids such as alanine, leucine and glutamic acid, does not adversely affect growth. If, however, tryptophane, or cystine, or histidine, or arginine has been removed from the mixture, a sharp decline in the weight of the animal is observed. These experiments give some idea of the synthetic powers of the mammalian organism, which is evidently able to build up the simple amino acids, but fails in respect of the heterocyclic."

Hopkins has built up at Cambridge a great research institute of physiological chemistry. A full-page portrait of him accompanies the article. M. E. W.

Friedrich Beilstein. Thoughts on the hundredth return of his birthday. F. RICHTER. *Ang. Chem.*, **51**, 101–7 (Feb. 19, 1938). —A historical review. L. S.

Mr. Hugh Ramage, 1865–1938. ANON. *Nature*, **141**, 961–2 (May 28, 1938).—In 1891 Mr. Hugh Ramage became demonstrator in chemistry under Professor Walter Hartley at the Royal College of Science, Dublin, where he assisted Sir Walter in researches on flame spectra. From 1904 until his retirement in 1930 Mr. Ramage was principal of the Technical Institute at Norwich. His first paper, published in 1895 in collaboration with Joseph Reddrop, was on the volumetric estimation of manganese by oxidation with sodium bismuthate. He also published papers on the spectrographic analysis of many minerals and metals, and discovered that Norwich flue-dust was a source of gallium. In recent years he applied the spectroscope to problems in biology and medicine. He showed that copper and silver are contained in differen parts of a mushroom, and extracted from half an ounce of dry pulverized mushrooms tiny pellets of silver and of copper. With Professor Munro Fox he showed that the manganese content of animal tissues varied with the locality in which a given species of animal lived and that strontium occurred in the genital duct of the edible snail. They found manganese in the liver of this snail and silver in the kidney and liver of all crabs and lobsters examined. This work led to the first mention of the presence of barium in the human choroid.

Mr. Ramage showed that a deficiency disease of Australian sheep could be cured with cobalt, the soil in the affected areas being deficient in this element. M. E. W.

Alchemy under James IV of Scotland. J. READ. *Nature*, **141**, 940 (May 21, 1938).—"James IV of Scotland was one of the most intelligent princes in Europe at the beginning of the sixteenth century." He was interested in medicine, surgery, physiology, alchemy, and psychology. Under the inspiration and direction of John Damian, "James established Scotland's first research laboratory in Stirling Castle...[and] provided his alchemist with an emolument and the necessary leisure for research by creating him Abbot of Tungland, in Galloway." Among the materials which Damian and his associates used in their attempts to prepare the Philosopher's Stone or Elixir of Life were gold, silver, quicksilver, aqua vitae [whiskey], saltpeter, sal ammoniac, litharge, salt, and sugar. "The Abbot's attempts to achieve the Stone were interrupted in 1507" when "he took off from the lofty battlements of Stirling Castle for a flight to Paris," equipped with feathered wings. He attributed his downfall to the fact that the wings were not made exclusively of eagles' feathers but partly of hen feathers, which had no natural tendency to soar. "The alchemical experiments in Stirling Castle were continued until 1513, when the interest of the Scottish crown in alchemy came to an untimely end with the death of James IV upon the tragic field of Flodden. A century and a half later this interest in science found a rebirth in two of James's distant descendants—Prince Rupert of Bavaria and King Charles II." M. E. W.

RECENT BOOKS

ELEMENTARY PRINCIPLES OF QUALITATIVE ANALYSIS. *T. R. Hogness*, Associate Professor of Chemistry, University of Chicago, and *Warren C. Johnson*, Associate Professor of Chemistry, University of Chicago. Henry Holt and Co., New York City, 1938. x + 325 pp. 27 figs. 14 × 22 cm. $1.40.

In this textbook, the authors have abridged and modified their earlier book, QUALITATIVE ANALYSIS AND CHEMICAL EQUILIBRIUM, which was reviewed in a recent number of this Journal [14, 448 (1937)]. Their purpose was to adapt the text for use in schools where qualitative analysis is given as a part of the course in general chemistry, rather than as a separate course.

The presentation of the theoretical portion of the subject, which occupies approximately two-thirds of the present text, remains unchanged, except for the elimination of the quantitative treatment of oxidation-reduction equilibria and half-reactions, and the omission of a few of the more difficult problems. The outstanding clarity of the discussion of the concept of chemical equilibrium, and the unusual wealth of authoritative information which is presented, were commented upon in the earlier review. The writer heartily concurs in the favorable opinion of the previous reviewer as to the excellence of this portion of the text.

A minor improvement might have been made in the discussion of amphoteric hydroxides, by the formulation of such anions as zincate and aluminate as hydroxyl complexes. Following the discussion of complex ions in the preceding chapter, the presentation of this viewpoint—at least, as an alternative to the traditional one—would have seemed especially appropriate.

In the portion of the book which deals with the properties of the ions and procedures for their identification, only ammonium, sodium, potassium, silver, lead, mercury, copper, tin, zinc, manganese, iron, chromium, aluminum, calcium, and barium, among the cations, have been included, while the treatment of anions is limited to chloride, nitrate, sulfate, carbonate, and sulfide. To some teachers, this restriction may appear too drastic, even for a short course. A brief discussion of the use of the centrifuge has been added to the section on manipulative procedures. The comprehensive table of physical properties of compounds, which constituted a distinctive feature of the earlier book, has been omitted.

The book is bound in paper covers, an innovation which results in a markedly lower price and increased convenience in handling, at the cost, however, of greatly decreased durability. This seems unfortunate, since the text contains so much theoretical material likely to be valuable to the student who pursues further work in chemistry, that it would be well worth preserving.

Typographical errors have been almost completely avoided. On page 136, however, "Fe^{++}" appears instead of "Fe^{+++}." It is doubtful whether such pentavalent cations as As^{+++++} and Sb^{+++++}, page 182, have any actual existence; and the statement on page 257 that manganates in the solid state are violet is undoubtedly erroneous.

Although the preliminary experiments are instructive and the procedures are adequately described, the authors have made no attempt to include the most recent improvements in analytical procedure, nor to furnish detailed directions for meeting every possible difficulty which might be encountered in practice. Emphasis is placed upon the application of principles, rather than upon instruction in analytical technic. This treatment is in accord with the authors' main purpose—to develop a thorough understanding of the subject of chemical equilibrium—which they have admirably fulfilled.

ARTHUR W. DAVIDSON

UNIVERSITY OF KANSAS
LAWRENCE, KANSAS

PHYSICAL CHEMISTRY. *J. N. Brønsted*, Professor in Copenhagen University. Translated by *R. P. Bell*, M.A., B.Sc., Fellow of Balliol College, Oxford. Foreword by *F. G. Donnan*, D.Sc., F.R.S., Professor of Chemistry in the University of London. Translation from the 1936 Danish edition. The Chemical Publishing Co. of New York, Inc., New York City, 1938, exclusive American agents. xv + 394 pp. 71 figs. 13.5 × 21.5 cm. $5.00.

This book is the basis of instruction in physical chemistry in the author's classes in Copenhagen University and the Danish Technical College. Its small size belies its content, for it is packed with good things from cover to cover. Condensation is achieved by the use of the thermodynamic approach and total lack of a discussion of experimental methods. The only subjects omitted that are found in the average text are the fundamental laws of chemical combination, and so forth, any discussion of the relationship between constitution and physical properties (except the parachor), and thermochemistry *per se*.

The thermodynamics of Willard Gibbs is used throughout, modified in the section on electrochemistry by the introduction of Guggenheim's electrochemical potential and Brønsted's electromotive potential of metals. However, the kinetic approach is not entirely ignored. Maxwell's and Boltzmann's equations are derived, in addition to the fundamental kinetic equation, and used thereafter, particularly in the chapter on reaction kinetics. Quantum mechanics is applied in connection with specific heats and other atomic and molecular processes.

The arrangement of subjects is logical. Opening with an excellent discussion of the laws of thermodynamics, the author takes up the states of aggregation, molecular theory, mixtures, the theory of dilute solutions (noteworthy), homogeneous equilibria, electrolytes (including an excellent discussion of the author's theory of protolysis) reaction kinetics (with a small amount of photochemistry), electrochemistry, affinity (especially commendable), and surface and colloid chemistry. Twenty-seven tables of illustrative material are incorporated in the text.

To American teachers the book will appear unusual in the absence of the attempt to picture mechanisms and structures and the total lack of problems and references. Several of the symbols are not in common use on this continent but are clearly defined and should occasion no difficulty. The typography leaves something to be desired.

To the teacher and advanced student Professor Brønsted's work should prove an invaluable stimulus. To the beginning student of physical chemistry it will probably prove more valuable as a reference than as a text. In brief, it is a physical chemist's physical chemistry.

MALCOLM M. HARING

UNIVERSITY OF MARYLAND
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COMBUSTION, FLAMES AND EXPLOSIONS OF GASES. *Bernard Lewis*, Ph.D. (Cantab.), Physical Chemist, U. S. Bureau of Mines Experiment Station, Pittsburgh, Pa., and *Guenther von Elbe*, Ph.D. (Berlin), Physical Chemist, Coal Research Laboratory, Carnegie Institute of Technology, Pittsburgh, Pa. Cambridge University Press, Cambridge, England, The Macmillan Co., New York City, 1938. xv + 415 pp. 75 figs. 14 × 22 cm. $5.50.

This most recent addition to the Cambridge Series of Physical Chemistry, edited by Professor E. K. Rideal of Cambridge University, maintains the high standard of its predecessors. The authors have set out to give a comprehensive and unified treatment of the important features of the oxidation of com-

bustible gases. The text is divided into four main parts entitled: (I) Chemistry and Kinetics of the Reactions between Fuel Gases and Oxygen; (II) Propagation of Flames; (III) State of the Burnt Gas; and (IV) Problems in Technical Combustion Processes. This is followed by three appendixes giving numerical data in the following fields: (A) Data for Thermochemical Calculations, (B) Limits of Inflammability, and (C) Flame Temperatures.

The great virtue of this book, to the reviewer's mind, is that the analyses of the problems involved are exact and specific. In a complex and rapidly developing field of this kind, there is always room for alternative explanations. The reviewer feels that the authors have been wise in emphasizing the published investigations (both theoretical and experimental) of themselves and their colleagues. A discussion, for example, of the relative merits of the hydrogen-oxygen mechanisms proposed by Semenoff, by Hinshelwood and Williamson, and by the authors would have been tedious and necessarily inconclusive. As it is, one has a clean-cut exposition of the features of this complex reaction. In addition, one is provided with references to alternative treatments.

Such a procedure involves a certain amount of arbitrariness, and may leave the reader with a feeling that the whole story has not been told. The fact of the matter is that the whole story cannot be told at the present time, as the authors emphasize in their preface. The requisite information is not yet available.

The general reader should be warned that the development is essentially mathematical. There is, however, usually sufficient interpretation and description to carry him through. The book can be recommended to all those who require a modern treatment of gaseous combustion processes.

ROBERT N. PEASE

PRINCETON UNIVERSITY
PRINCETON, NEW JERSEY

GLENN-WELTON CHEMISTRY ACHIEVEMENT TEST. *Earl R. Glenn* and *Louis E. Welton*. World Book Company, Yonkers-on-Hudson, New York, 1938. Test 1, Form A, $1.30 for twenty-five copies; Test 2, Form A, $1.30 for twenty-five copies.

This test, entirely objective, is written primarily for the purpose of analyzing the achievement of students in the first-year high-school chemistry, the results to be used as a basis for improving their work. The test is in two sections, Test 1 to be used at the end of the first semester and Test 2 at the end of the second semester. Each of the two tests has five parts. Part I measures the students' range of information of chemical facts. Part II contains drawings representing chemical principles and questions to determine whether the students understand the principles. Part III measures associational vocabulary. Part IV contains drawings of laboratory apparatus and questions concerning their use and operation. The last, Part V, measures the students' knowledge of and ability to solve equations and problems. Test 1 covers the parts of the subject usually taught in the first half year's work, and Test 2 the parts usually taught in the second half year.

There are two forms, A and B, similar in content, organization and equivalent in difficulty having coefficients of 0.91 ± 0.01. The questions are based upon a study of ten widely used textbooks. The reliability coefficients of Test 2 is 0.93 ± 0.01, and if both forms are used 0.96 ± 0.01.

A continuous period of seventy-one minutes is required to administer the test. This is a rather long period of sustained attention for high-school students; to break the time would invalidate the reliability of the norms. The total number of points are 128 and 124, a sufficient number to distribute the students satisfactorily. A manual of directions and norms is provided.

The questions are interesting and challenging and are arranged with increasing difficulty, thus encouraging the weaker students. In most cases the questions are clearly stated and should be easily understood. The ingenious use of many illustrations breaks the monotony of the usual test. In some instances the object or the diagram are not familiar to all students and in many cases the use of the illustration is of no aid, as, for example, a picture of a storage battery or a Pyrene fire extinguisher. The number of errors is small. The elimination of considerable duplication, the addition of the periodic chart and the E.M.F. series would improve the test.

On the whole, the test is a good one, neither too difficult nor too easy for high-school students, for the authors have sampled the representative and interesting parts of the high-school course with discrimination.

O. M. SMITH

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SINN UND AUFGABEN DER GESCHICHTE DER CHEMIE (The Sense and the Profits of the History of Chemistry). *Dr. Erich Pietsch*, Editor-in-Chief of Gmelin's "HANDBUCH DER ANORGANISCHEN CHEMIE." Verlag Chemie, Berlin, 1937. 15.5 × 23 cm. 33 pp. RM. 0.90.

In this essay the author argues for the cultural value of the study of the history of chemistry, basing his conclusions on an examination of the interrelations between the history of chemistry and the cultural changes which have occurred in the Occident during the past century. The study, he says, is practical because it teaches us how to avoid the pitfalls into which investigators in the past have fallen, but it is most valuable because of the understanding insight which it gives us into the cultural connections of the history of humanity

TENNEY L. DAVIS

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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STEROLS AND RELATED COMPOUNDS. *E. Friedmann*, M.D., Ph.D. With a foreword by *Professor Sir Frederick Gowland Hopkins*, O.M., F.R.S. Chemical Publishing Company of New York, Inc., New York City, 1937. ix + 100 pp. 153 figs. 16 × 23.5 cm. $3.00.

This book, which is based on a series of lectures given at the Sir William Dunn Institute of Biochemistry at Cambridge during the autumn term of 1936, is an attempt to present to the non-specialist the more significant advances in the development of our knowledge of the steroids. The author "has dealt with the development of the subject on historical lines, and presented the more significant stages of that development in logical sequence." The treatment of the structural interrelationships and physiological properties of the various groups of steroids is adequate if not thorough.

In Lecture I the author wisely omits any discussion of the complex oxidative ring openings which led to the old formulas for cholesterol and the bile acids, and instead shows how Wieland-Barbier degradations and side-chain oxidations led to the correlation of the sterols and bile acids. The remainder of the lecture treats of scymnol; the stereochemistry of the bile acids; plant heart poisons; toad poisons; and the digitalis saponins. In Lecture II the progress made in the study of Vitamin D is described, including the biological experimentation leading to the linking of ergosterol with pro-vitamin D, the irradiation products of ergosterol, and the recent work on other 7-dehydro-sterols. Lecture III describes first the biological and chemical investigations which have led to our present knowledge of the sex hormones, and concludes with a survey of the work of Cook, Fieser, and others on carcinogenic hydrocarbons.

On the whole, this work is free of gross misstatements. A few errors should, however, be noted. The structure of scymnol (pages 21–4) is not definitely established, but it is certain, contrary to the author's treatment, that scymnol contains no 3-hydroxyl group, for the triketocholanic acid obtained from scymnol is not identical with dehydrocholic acid. The author's use of *hydrochloride* for *chlorohydrin* (page 23) is indicative of a number of errors of another type. Contrary to the author's statement (page 54), ring closure from calciferol to pyrocalciferol generates only *one* assymmetric center.

The only noteworthy omission is that of the cortical steroids. While little was known of these at the time of delivery of the lectures, it does seem that some discussion of the chemistry could have been introduced in the later, published version.

While this book adds nothing new to the subject, and will be of only passing interest to the specialist, it succeeds admirably in achieving the purpose for which it was intended, the presentation of a simple, lucid, account of progress in the steroid field. It would be desirable to have more books of this character dealing with progress in fields such as those of alkaloids, porphyrins, and so forth.

RUSSELL E. MARKER

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THE PENNSYLVANIA STATE COLLEGE
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NUMERICAL PROBLEMS IN ADVANCED PHYSICAL CHEMISTRY. *J. H. Wolfenden.* Oxford University Press, New York City, 1938. xx + 227 pp. 14 × 22 cm. $2.75.

This book is an attempt to bridge the gap between the laboratory experience of the average student in elementary physical chemistry and the theoretically interesting problems of modern advanced physical chemistry with which he may have but a textbook acquaintance.

The work consists of one hundred and thirty-three problems in the following groups: fundamental constants, stoichiometry, gaseous equilibria, heterogeneous equilibria, thermochemistry and miscellaneous thermodynamics, conductivity of solutions and transport numbers, equilibria in solution, miscellaneous electrochemistry, kinetics of thermal reactions, photochemistry, molecular structure, crystal structure, radioactivity. The problems have been chosen from English and American chemical journals of the last fifteen years. With each problem there is given the necessary data for the solution, reference to the original literature, reference to standard textbooks where the subject is treated, notes on the solution of the problem. The answers, often in detail, are given in the back of the book. A table of useful constants, factors, and their logarithms is included.

The problems chosen are strictly of an advanced nature, as is indicated by the titles of the problems in one of the shorter groups, miscellaneous electrochemistry; the heat of solvation of ions; standard electrode potentials in methanol; an experimental test of the interionic attraction theory applied to heats of dilution; the kinetics of the electrolytic discharge of hydrogen and oxygen from aqueous solution; the electrolytic separation of deuterium; and the deuterium content of ordinary water and the electrolytic separation of the oxygen isotopes.

The author has chosen important and typical problems, the solution of which cannot help but provide excellent training for students (and teachers) of advanced physical chemistry. This carefully prepared compilation should be of interest to every conscientious teacher of advanced students who desires to make sure that the experimental basis and method of calculation for many theoretical topics is understood.

E. ROGER WASHBURN

UNIVERSITY OF NEBRASKA
LINCOLN, NEBRASKA

TECHNICAL ANALYSIS OF ORES AND METALLURGICAL PRODUCTS. *Franklin G. Hills*, Colorado School of Mines. First edition, lithoprinted. Chemical Publishing Company of New York, Inc., New York City, and E. & F. N. Spon, Ltd., London, 1937. xi + 198 pp. 10 figs. 13.5 × 21.5 cm. $3.00.

After a foreword by E. D. Kinney, University of Kansas, a brief introduction, a page of bibliography (textbook titles) and two pages of discussion of decomposition methods used for ores, the book contains descriptions of processes for the analytical determination of twenty-nine metals and non-metals. The metallurgical products indicated in the title are two: nonferrous slags and cyanide mill solutions. The last division in the text deals with standard solutions and standardizing, five solutions being discussed: potassium permanganate, potassium dichromate, ammonium molybdate, potassium ferrocyanide, and sodium thiosulfate. There is no discussion of the purity of the primary standards used for these standardizations and no precautions are suggested, the apparent assumption being that they are "pure." This is a dangerous assumption, as every analyst knows.

The analytical methods described are accepted methods, for the most part, and the directions given may safely be followed although in some cases the decomposition of ores and minerals is treated too briefly and too generally.

The style is somewhat stilted and the English could be considerably improved. The chapters are not numbered in the text and the illustrations are neither numbered nor, in most cases, titled. Conventional rules of composition and publication are extensively violated and the material appears to have been rather hastily thrown together. This being a first edition, no doubt considerable improvement will be noticed in subsequent printings.

It is difficult to find any compliments for the publishers, so far as their part in the job of book making is concerned. The book is carelessly lithoprinted, fourteen pages scattered through the book being photographed to smaller type size than prevails on the other pages. The margins are so narrow that the binding brings the text so close to the stitching as to make it nearly impossible to read the text without first "breaking the back" of the book.

The volume is well stitched and the cover has a very nice appearance.

E. G. MAHIN

UNIVERSITY OF NOTRE DAME
NOTRE DAME, INDIANA

THE CATALYTIC ACTION OF SURFACES. *J. E. Nyrop.* Second edition. Levin and Munksgaard, Copenhagen, 1937. 98 pp. 20 × 27 cm. $3.00.

The second edition of THE CATALYTIC ACTION OF SURFACES contains twenty-seven more pages than the first edition and a number of corrections and alterations. The author's aim has been to present his own theory of surface catalysis to which he was led by the observation that chemical reaction by means of electron bombardment occurs only when the conditions are such as to cause the ionization of the reactant most difficult to ionize. The application of this fact as the basis of the author's theory is stated in the form of two postulates as follows.

(A) In a chemical reaction furthered considerably by the presence of a surface, the surface is at the temperature in question able to ionize those molecules among the reactants most difficult to ionize and the surface will cause a strong adsorption as ions formed are attracted by the surface.

(B) A surface able to ionize molecules of a gas or liquid and hence able to yield a strong adsorption, produces an increased adsorption when the molecules are substituted by others having a lower ionization potential, assuming that all other conditions are the same.

The reviewer believes that the theory advanced by the author is very worth while, but because of the many errors which the book contains and the lack of completeness in mathematical derivations one gets a poor impression of the book as a whole and wishes the original had been in the author's native language, as the reviewer feels the author's theory is worthy of careful consideration. It may be well to call attention to the fact that ideas similar to those of the author have been suggested by others [*Cf. Chem. Abstr.*, **22**, 2512 (1928)].

This book is not interesting from the standpoint of chemical education.

J. C. W. FRAZER

JOHNS HOPKINS UNIVERSITY
BALTIMORE, MARYLAND

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On August 15th, Corning Glass Works began distribution of their new "Pyrex" brand laboratory catalog LP-18. This catalog is the most comprehensive that Corning has offered. It contains one hundred twenty-eight pages, and carries 2353 individual items, of which over seven hundred are listed for the first time. Some of the features of the new catalog are that practically all ground joints, stoppers, and stopcocks listed are now interchangeable; number of pieces per package reduced on many items; and prices are reduced on more than five hundred items, including centrifuge tubes, condensers, distilling flasks, T ground joints and connections, separatory funnels and stopcocks, tubes for clinical laboratories, as well as some generally used sizes of test-tubes, tubing, and rod.

Monastral

A new pigment color, "Monastral" Fast Blue GS, is announced by the Dyestuffs Division, *E. I. du Pont de Nemours & Company*. It is designed for use in coloring paints, lacquers, wall papers, soap wrappers, and similar materials. Very close in shade to Peacock Blue, it is greener than "Monastral" Fast Blue BSN. Like the BSN type, the new color has demonstrated fastness to light, acids, alkalies, and lime, and does not bleed in oil, water, or alcohol. Because of the greenness of shade, it is expected to be useful for fast greenish blues and in combination for bright greens.

Diglycol Stearate

For the lubrication of aluminum, brass, and other metals for drawing, stamping, and extrusion, diglycol stearate is arousing considerable interest.

Neutral, stable, non-toxic, and easily compounded lubricating compounds are very quickly made with diglycol stearate as a base. If desired, the slight film which sometimes remains after working the metal is very easily removed with warm water. No solvents are necessary. The use of diglycol stearate permits the drawing of 0.01 gage brass up to six stages with subsequent stamping without the necessity for further lubrication. In many cases, diglycol stearate has been found to decrease the wear on the dies. Cleaner and longer extrusions permanently free of acid or alkali stains are obtained.

Further details will readily be given by the manufacturers, the *Glyco Products Co., Inc., 148 Lafayette St., New York City.*

New D.-C. Explosion-Proof Motor

A complete new line of D.-C. Explosion-Proof motors has just been announced by the Louis Allis Co. of Milwaukee.

This new line incorporates eighteen separate and distinct improved features.

These new D.-C. Explosion-Proof motors have been inspected and explosion tested by the Bureau of Mines Laboratory and have also been tested, listed, and approved by the Underwriters' Laboratories.

Copy of Bulletin No. 520 illustrating and describing this new line of motors will be sent upon request to *The Louis Allis Co., Milwaukee, Wis.*

R. L. Van Name Company Now a Division of Will Corporation

The *R. L. Van Name Company, 95 Madison Avenue, New York City,* manufacturers of microchemical and special laboratory apparatus, has been made a division of the *Will Corporation of Rochester, New York.* The name and personnel will remain the same under the continued direction of R. L. Van Name.

Tamworth-Glasbake Catalog

The first edition of Tamworth-Glasbake Laboratory Glassware Catalog has just been published by *Tamworth Associates, Inc., Needham Heights, Mass.* According to the catalog, Tamworth-Glasbake Products are made from an extremely low expansion glass of a composition melted for many years for use as oven ware and other heat-resistant products, and sold under the trade name "Glasbake." Glasbake glass is a borosilicate glass, being alkali free, and resistant to acids. For the first time it is now offered in suitable shapes and forms for laboratory uses under the trade name Tamworth-Glasbake. Copies of the catalog may be had by writing the manufacturer.

Molybdenum Wire, Rod, and Sheet

The availability of molybdenum, in the forms of round wire and rod, and in sheets has been announced by the *Westinghouse Electric & Manufacturing Company.*

The wires and rods are from one-thousandth of an inch to three-fourths of an inch in diameter. The sheets are up to several inches in width and from $2^1/_2$ to 30-thousandths inch thick. This product is unique in its resistance to high temperatures, at the same time being workable with relative ease.

When used as heater winding on hydrogen furnaces it is entirely unattacked by the hydrogen, and its life is much longer than that of any other available material. It does not amalgamate with mercury to any great extent, making it valuable for use in mercury switches and in laboratory applications. It may also be used for sealing through the walls of glass vessels made of certain grades of hard glass.

Ductile molybdenum in sheet form is useful for "boats," or long boxes for treating material in high temperature hydrogen furnaces.

New Instrument Catalog

A new 64-page catalog entitled "TAG Indicating, Recording and Controlling Instruments for Temperature and Pressure" has just been published by C. J. Tagliabue Mfg. Co. It is more than a regular listing catalog for it presents information in a clear, understandable way on the latest TAG Instrument Developments.

In addition to the new line of Recording Thermometers and Recording Pressure Gages with 10- and 12-inch charts, complete data will be found on Indicating and Recording Controllers. The control instruments are listed in either the "On-Off" model for all ordinary control applications, or the Throttling model for use where any considerable apparatus lag is encountered.

Many illustrations not only show how these pressure-spring instruments operate, but the practical installation photographs tell an interesting story of what they are doing for the process industries.

A copy of Catalog 1060D will be sent free by addressing *C. J. Tagliabue Mfg. Co., Park and Nostrand Aves., Brooklyn, N. Y.*